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Beyond the Water's Edge:
United States National Security & the Ocean Environment

A Thesis
Presented to the Faculty
Of
The Fletcher School of Law and Diplomacy

By

JOHN MARK DI MENTO

In partial fulfillment of the requirements for the
Degree of Doctor of Philosophy

DECEMBER 2006

Dissertation Committee
William Moomaw, Chair
Richard Shultz
Robert Frosch

TABLE OF CONTENTS

JOHN MARK DI MENTO
COMMANDER, UNITED STATES NAVY

EDUCATION & PROFESSIONAL EXPERIENCE:

2005-Present Staff Oceanographer
COMMANDER, UNITED STATES SECOND FLEET
Norfolk Naval Base, Norfolk, Virginia

CDR DiMento serves as advisor to the Commander for meteorological and oceanographic impacts on Second Fleet units and missions. He trains and supervises a forecast watch team to provide timely and accurate environmental forecasts in support of safe and efficient fleet operations and makes go / no-go fleet sortie recommendations to the Commander in advance of tropical storms. CDR DiMento served as a special advisor to the Joint Force Maritime Component Commander and as the Navy liaison to the forward headquarters of Joint Task Force Katrina, the multi-service and interagency humanitarian assistance and disaster response effort in the wake of the most devastating natural disaster in United States history.

2002-2005 PhD Candidate In-Residence
FLETCHER SCHOOL OF LAW & DIPLOMACY
Medford, Massachusetts

Upon completion of his MALD degree at Fletcher, CDR DiMento acceded to PhD Candidacy, completed additional required coursework, passed Comprehensive Exams and began his dissertation research and writing while still in residence at Fletcher. He then transferred back to the Fleet where he continued to add to the experiences that form the backbone of his present-day case study research on the intersection of ocean environment, ocean science and security.

2000-2002 Graduate Student, Master of Arts in Law & Diplomacy Program
FLETCHER SCHOOL OF LAW & DIPLOMACY
Medford, Massachusetts
Degree Awarded: **Master of Arts, Law & Diplomacy**

CDR DiMento entered the International Security Studies program at the Fletcher School on a grant awarded by the Office of Naval Research to pursue research related to the intersection of oceans and national security. There he combined his oceanographic background with his military experience to study environmental security in conjunction with the International Environment and Resources Program.

1998-2000 Fellow, Georgetown University Government Affairs Institute
Military Legislative Assistant
U.S. SENATOR TRENT LOTT, SENATE MAJORITY LEADER
United States Senate, Washington, D.C.

Working for Senator Lott's National Security Advisor, CDR DiMento was responsible for research and analysis of military and national security issues related to the State of Mississippi and of those issues of a national scope that were of concern to the Senator as a result of his Committee assignments and position as Majority Leader. He drafted legislation, testimony, correspondence, statements and speeches for Senator Lott, and served as an interface between the Senator's staff and the military services.

1996-1998 Oceanographer
USS KEARSARGE (LHD-3)
Norfolk Naval Base, Norfolk, Virginia

As Ship's Oceanographer, CDR DiMento was responsible for tactical environmental support to the ship, embarked Amphibious Squadron and Marine Expeditionary Unit staffs, Air Combat Element, amphibious landing craft detachments, and ships in company. He is qualified on the bridge as Officer of the Deck (Underway), Command Duty Officer (Inport), and Combat Information Center Watch Officer. He was additionally in charge of the Damage Control Training Team, planning and executing drills to train ship's personnel in all aspects of damage control. During Operation Noble Obelisk in June of 1997, CDR DiMento was responsible for the processing, coordination and care of over 2500 evacuees from the civil war in Sierra Leone, the largest Noncombatant Evacuation ever executed by a single ship of the U.S. Navy.

1993-1996 Flag Lieutenant and Executive Assistant to the Commander
NAVAL METEOROLOGY AND OCEANOGRAPHY COMMAND
Stennis Space Center, Mississippi

As Flag Lieutenant, CDR DiMento was responsible for the planning and execution of all official travel for the Admiral to visit his 65 subordinate sites worldwide or to government and civilian offices home and abroad. As Executive Assistant he was responsible for the smooth and efficient operation of the Admiral's front office and the effective staff preparation of all issues that reached the Admiral's attention.

1991-1993 Assistant Operations Officer
OPERATIONAL OCEANOGRAPHY CENTER (OOC)
NAVAL OCEANOGRAPHIC OFFICE
Stennis Space Center, Mississippi

Within the OOC, CDR DiMento coordinated Fleet Support providing tailored oceanographic products to fleet units worldwide. These products ranged from acoustic prediction model runs to satellite imagery. He was additionally the subject matter expert for the On-Scene Spill Model, developed by NOAA to predict oil spill movement and used by the Navy to provide exercise support for Joint Logistics Over The Shore (JLOTS) exercises. CDR DiMento achieved qualification as a Naval Aviation Observer, flying Fleet Support exercises with Oceanographic Development Squadron Eight during his tour at NAVOCEANO.

1990-1991 Executive Officer
OCEANOGRAPHIC UNIT THREE
Gulfport, Mississippi

Deployed on the USNS H.H. Hess, Oceanographic Unit Three conducted well over 100,000 miles of classified ocean surveys for the Naval Oceanographic Office in one year deployed. CDR DiMento served as the second-in-command and administrative head of the unit, responsible for thirty embarked personnel.

1990 Action Officer
OFFICE OF THE OCEANOGRAPHER OF THE NAVY
United States Naval Observatory, Washington, D.C.

CDR DiMento served as an action officer in the Program Integration division on the staff of the Oceanographer of the Navy while awaiting orders to Oceanographic Unit Three.

1987-1989 Graduate Student, Applied Ocean Science
SCRIPPS INSTITUTION OF OCEANOGRAPHY
La Jolla, California
Degree Awarded: **Master of Science, Oceanography**

Selected for immediate graduate education and awarded a scholarship by the Naval Academy Alumni Association, CDR DiMento concentrated his research in the area of satellite remote sensing. His Master's Thesis was one of the first papers to investigate mesoscale ocean variability utilizing satellite altimetric data and the basis of a work subsequently published in the Journal of Physical Oceanography.

1983-1987 Midshipman
UNITED STATES NAVAL ACADEMY
Annapolis, Maryland
Degree Awarded: **Bachelor of Science, Electrical Engineering**

CDR DiMento was graduated with honors from the United States Naval Academy. He was selected to the Tau Beta Pi, Sigma Pi Sigma, Phi Alpha Theta, and Phi Kappa Phi Honor Societies; and for achieving the highest overall average in the Naval Weapons curricula, he was awarded the Class of 1871 Sword.

CDR DiMento is qualified as a Surface Warfare Officer and as a Naval Aviation Observer / Flight Meteorologist. He has been awarded the Meritorious Service Medal, multiple awards of the Navy and Marine Corps Commendation Medal and Navy Achievement Medal, as well as numerous unit and service awards. CDR DiMento is married to the former Chenaey Bourgeois of Bay Saint Louis, Mississippi and has two daughters, Colby and Audrey, and one son, Jack.

ABSTRACT

Scientific study of the oceans originated in the United States essentially as a function of national security. Investigations that focused on the tactical and operational impacts of the fluid, geophysical, chemical and biological marine environment upon U.S. Navy operations successfully addressed many challenging naval requirements; but oceanographic inquiry in support of naval needs also triggered unexpected results. In many instances the knowledge of the oceans that was acquired through directed studies - and through complementary lines of inquiry that were enabled by tools developed for naval oceanographic research - further impacted national security in ways that were not anticipated and which transcended tactical and operational significance and could be considered of more strategic consequence. Through selected case studies, the present work explores relationships between the oceans, ocean science and national security through almost the last two hundred years during which the study of the marine environment has held relevance for naval operations.

A number of important insights are revealed in the individual case studies of *Beyond the Water's Edge*, and as a result of themes that repeat despite considerably different contextual parameters within and across each of the cases that are considered. As matters which address the intersection between the natural environment and security, each of these cases supports the conclusion that environmental impacts on military operations are more central to the discipline of environmental security studies than heretofore considered. In addition, a more consilient interdisciplinary viewpoint of environmental security appears necessary to appreciate how significant matters of the environment are to international security studies. The cases also support the hypothesis that securitization of environmental parameters is an important factor for supporting research into otherwise formidable areas that might remain beyond understanding without a security imperative, and which as a result engender additional security considerations which might otherwise not have developed. And logically, when consilient viewpoints afford a better understanding of the manner in which ocean science illuminates, underpins and expands environment-security relationships, they provide critical insights to policy makers responsible for the oversight of oceanographic research in support of national security and other national interests of the United States.

For Chenaey

Colby, Audrey & Jack

Mizpah

ACKNOWLEDGEMENTS

Writing *Beyond the Water's Edge* has been an effort that I won't soon forget – not only for the work that goes into such an undertaking, but because of what I learned along the way about people and events for which I have an altogether new respect. Naval oceanography answered the bell for some extremely serious challenges to United States national security, and both distant predecessors and senior colleagues that I served with throughout my career played pivotal roles in events that not only populate the pages of this work, but that truly deserve recognition in history. For the many ways that the men and women of naval oceanography applied their knowledge, intuition and ingenuity – and in some cases raw determination and courage in times of personal danger – I remain in awe and hope that in some small measure what is recounted in these pages keeps alive the legacy of their accomplishments for those who follow in extremely-hard-to-fill footsteps. I feel very fortunate to have met some of these pathfinders and to have heard the personal recollections that color even more vividly the events in which they took part. They remind me that there are always more facets to a situation than history records, and that perspective is critical to understanding.

For the many people to whom I owe a debt of thanks related to this dissertation, I cannot begin to succeed in identifying them all or enumerating what they did that made possible the completion of *Beyond the Water's Edge*. My Committee is without a doubt one of the most elite trios I could have endeavored to put together to oversee this work. They let me explore, and while they tugged occasionally on the reins they provided me the freedom to pursue what I thought to be the best avenues to explain the processes underway in the world of the ocean environment, science and security. To my Chair, Bill Moomaw, I owe a special debt for his guidance and interest in my work throughout my time at Fletcher. He defines for me the word "interdisciplinary" and personifies another: "class."

Of the many naval oceanographers with whom I have served and shared sea stories with over the years, two stand out as the individuals who most encouraged me down this path: Vice Admiral Paul Gaffney and Dr. Steve Ramberg. Without their support, this entire effort simply would have not taken place.

Professors Bob Pfaltzgraff's and Dick Shultz's expertise and guidance make the International Security Studies Program a center of gravity at Fletcher. Always in demand these gentlemen made time and cleared the path for a naval officer to travel a road not taken.

Professor Bob Frosch not only played a role in advising me throughout this dissertation. He played a central role in some of the major events that are recounted regarding Cold War oceanography. Sir, in addition to my thanks you have my sincere respect.

Many people at Fletcher deserve my individual gratitude, but I would fail in the attempt to remember them all here. Nevertheless, there are some whom I would particularly like to mention. To a whole group of very talented and special ladies who have played an important part throughout my tenure – Freda, Roberta, Bernie, Fran, Nela, Jenifer, Nora, Ann Marie, Carol, Laurie, Paula, Marie-Smith, Jane, Miriam, Linda, Barbara, Karen, and Giovanna – you are the Steel Magnolias of Fletcher that warm and color an institution in ways that defy job description and role. Your professional assistance never wavered, and your personal interest and warmth in sharing my life at Fletcher made my experience there ever so much richer.

For my friends and shipmates, I am extremely grateful. We walk in and out of each others hectic lives but pick up where we left off. Your shoulders have helped to bear the load, and you have been family when we had to be away from our own. Thank You.

There are not the words to make up for time away from family, and *Beyond the Water's Edge* certainly kept the author sequestered in the office for many, many, *many* hours. For their love and support, this work is dedicated to my wife and to my children.

ΨΨΨ Cur Non ΨΨΨ

ΨΨΨ Chapter 1 The Oceans, Ocean Science & United States National Security ΨΨΨ

Beyond the Water's Edge is an exploration. It is a journey that travels the boundaries where the natural sciences and political sciences intersect in an effort to examine their relevance to each other, and by identifying and demonstrating previously unrecognized relationships to provide explanatory power to a field which should naturally demonstrate interdisciplinary coherence but to date has largely failed to do so: environmental security. The topics which are investigated all relate to the oceans and the ways in which security interests intersect with environmental parameters as a result of naval operations. The genesis of this journey is the author's career as a naval oceanographer and the realization that the existence of such an occupation stems from the importance of the ocean environment to and influence upon naval endeavors. Present day interactions between the ocean environment and security underpin the bulk of this work, but historical cases are explored to reveal the enduring relationships that have existed since ocean science was first applied to matters of naval importance.

As a work of social science, this study is grounded in international security studies – the field which focuses upon the importance of security as a matter of human society. Environmental security is a relatively new subset of security studies and has thus far gained only nominal traction as a discipline because much of the research remains speculative and has yet to generate conclusive explanatory power demonstrating that the environment may prove a source of conflict – the bulk of the work in the field to date. The author contends that environmental security needs to be considered from a broader perspective, one that includes additional ways that the environment and security intersect besides as a potential catalyst for conflict, and in addition that multidisciplinary viewpoints are necessary to frame the relevance of the environment to security studies. This unification of knowledge across disciplinary lines is known as consilience. From a consilient approach, *Beyond the Water's Edge* will reveal that environmental factors have long played critical roles in matters relevant to security – not only for their impact on military operations, but in broader ways that influence the course of international relations that evolved as second order effects as a result of the oceanographic investigations into their initial roles as factors of naval importance.

Scientific study of the oceans originated in the United States essentially as a function of national security. Investigations that focused on the tactical and operational impacts of the fluid, geophysical, chemical and biological marine environment upon U.S. Navy operations successfully addressed many challenging naval requirements; but oceanographic inquiry in support of naval needs also triggered unexpected results. In many instances the knowledge of the oceans that was acquired through directed studies - and through complementary lines of inquiry that were enabled by tools developed for naval oceanographic research - further impacted national security in ways that were not anticipated and which transcended tactical and operational significance and could be considered of more strategic consequence. Through selected case studies, the present work explores relationships between the oceans, ocean science and national security through almost the last two hundred years during which the study of the marine environment has held relevance for naval operations.

A number of important insights are revealed in the individual case studies of *Beyond the Water's Edge*, and as a result of themes that repeat despite considerably different contextual parameters within and across each of the cases that are considered. As matters which address the intersection between the natural environment and security, each of the cases supports the conclusion that environmental impacts on military operations are more central to the discipline of environmental security studies than heretofore considered. In addition, a more consilient interdisciplinary viewpoint of environmental security appears necessary to appreciate how significant matters of the environment are to international security studies. The case studies presented also support the hypothesis that securitization of environmental parameters is an important factor for supporting research into otherwise formidable areas that might remain beyond understanding without a security imperative, and which as a result engender additional security considerations which might otherwise not have developed. And logically, when consilient viewpoints afford a better understanding of the manner in which ocean science illuminates, underpins and expands environment-security relationships, they will provide critical insights to policy makers responsible for the oversight of oceanographic research in support of national security and other national interests of the United States.

Consilience & Environmental Security

Environmental security developed as a concept after the Cold War when political scientists identified environmental problems as potential instigators of conflict, but struggled because specific cause-and-effect relationships – while intuitive and plausible – largely failed to demonstrate convincingly that environmental issues initiated strife in the absence of substantial exacerbating factors and on a scale that provided explanatory power for the future of international relations. That does not mean that environmental security should be shelved as a matter of political science or a matter of international security studies. Rather, environmental and security issues need to be considered from a broader perspective that appreciates the many ways in which the natural environment and security intersect and how pervasive the relationships actually are. Cross disciplinary expertise is necessary to translate some of the ways in which environmental problems influence security concerns and vice versa. This is immediately evident in attempts to link environmental issues to various forms of conflict. Traditional resource disputes are understandable enough when they involve the ownership or access to environmental resources such as oil, fish, or arable land, but when coupled to matters of environmental change some of these resource issues become more subtle and may involve second order effects that extend beyond the catalytic issues themselves. Changes may be natural or influenced by man's use of the environment which alters resource distribution or accessibility directly or indirectly, and in considering anthropogenic effects one must also include the occasional environmental insult (pollution) by one entity which affects another.

In addition to environmental issues serving (potentially) as proximate causes for tension and perhaps under the right conditions leading even to conflict, two additional relationships bind the environment with security essentially without debate: the influence of environmental parameters on military operations, and the impact of military operations on the environment. And these two intersections - while they may prove independently to be of considerable scope and replete with substantive issues by themselves - can have corresponding impacts on security through the ways they influence other matters of international relations including international law. It was from the latter two perspectives related to environmental impacts on the conduct of naval operations and the corollary impact of naval operations upon the marine environment that

the themes of this dissertation developed. But while the author's interests began in this somewhat narrowed subset of environmental security, it quickly became apparent that more complete explanations and appreciation of the ramifications of issues in these areas could only be fully realized through a more comprehensive view that transcended other general intersections between issues of the environment and security – in the process illuminating an important theme: environment-security relationships require an interdisciplinary approach to follow the threads through rather extensive feedback loops which come back to influence other areas of environmental security apart from where they began. It is this cross-disciplinary requirement that makes a more complete understanding of environmental security in the oceans a matter of consilience – "the linking of facts and fact-based theory across disciplines to create a common groundwork of explanation."[1]

Consilience as expressed by biologist and Pulitzer Prize-winning science author E.O. Wilson is an effort to unify knowledge across disciplines of learning. Wilson particularly expressed hope that more consilient viewpoints would bridge the social and natural sciences in general, although as an evolutionary biologist he focused his attentions on the intersection of social sciences with biology, psychology and biological anthropology. But consilience is not a concept that links only these particular fields; rather the goal is to apply what is learned in one field of the social and natural sciences to better understand issues in another – linking academic disciplines that do not traditionally coordinate research, but that each have something to contribute to the particular understanding of subjects of interest to more fully explain them at multiple levels of analysis. "It is not enough to say that human action is historical, and that history is an unfolding of unique events. Nothing fundamental separates the course of human history from the course of physical history, whether in the stars or organic diversity."[2]

In Wilson's view cross-disciplinary expertise is necessary to address most pressing problems of the day, "…ethnic conflict, arms escalation, overpopulation, abortion, environment, endemic poverty …cannot be solved without integrating knowledge from the natural sciences with that of the social sciences and humanities. Only fluency across the boundaries will provide a clear view of the world…. Yet the vast

[1] Edward O. Wilson, *Consilience: The Unity of Knowledge* (New York: Vintage Books, 1998), 8.
[2] Ibid., 11.

majority of our political leaders are trained exclusively in the social sciences and humanities, and have little or no knowledge of the natural sciences." For those facing complex problems while constrained by narrow training or outlooks, solutions will prove difficult, "A balanced perspective cannot be acquired by studying disciplines in pieces, but through pursuit of consilience among them."[3] Wilson illustrates his point by asserting that political scientists failed to anticipate the fall of communism by overestimating political strength and underestimating the strength of ethnic strife within the Soviet Union, a factor that blossomed when Russia exerted less control over its former spheres of influence when the Soviet Union broke apart. Writing in 1998 he also claimed that political theorists consistently "misjudged Muslim fundamentalism, which is religion inflamed by ethnicity."[4] It was a rather prescient example considering what has happened in the interim. Failure to explain phenomena, according to Wilson, is a failure to establish linkages across adjacent levels of organization. To more fully examine environmental security from a naval perspective, this study seeks to extend the analyses beyond simply environmental impacts on security to the science behind issues and to ramifications that occur through complex feedbacks which further complicate security relationships or expand them into new areas entirely.

Environmental security is a difficult concept to bound. Merging two terms that are inherently ambiguous in their definition and scope, it is a concept fated to be viewed differently by each who would consider its meaning. Security is a term that requires a referent – what is to be secured; a perspective – for whom; and a threat – from what? Environment is a term that can be interpreted across a spectrum of possible meanings, from physical surroundings that may be either natural or manmade to a psycho-social interpretation a la the *milieu* of international relations theory - itself a construct of geospatial perspective developed by political geographers and historians. Taken together, the permutations of possible interpretations of what comprises environmental security span a very broad spectrum. Without being too literal or simplistic, the concept of environmental security nevertheless can be viewed through a straightforward if rather wide-angled lens. I will use the term environment to mean the natural physical environment: the terrestrial, oceanic and atmospheric regimes of planet Earth. And I will fix the term security to referent perspectives as defined in the academic discipline of security studies: national,

[3] Ibid., 14.
[4] Ibid., 200.

international, regional, subnational, transnational, or supranational (global) security – implying that the 'what is to be secured' and 'from what' questions are approachable from the perspective of a single state; as viewed by the community of states writ large or within smaller groupings of states geographically; from a perspective that forms a subset within political borders or that transcends political borders and incorporates groups defined by ethnic, religious, cultural or other demographics; and from an overarching perspective that affects society independent of political, social or other groupings. In those cases where the natural environment impacts or influences matters for any of the referent levels of security, they may be considered as environmental security issues. Environmental security can thereafter be separated into more manageable subdivisions that incorporate:

- the impact of environmental change on political relations and security;
- the impact of insults to environmental integrity on political relations and security;
- the impact of environmental resource disputes;
- the impact of the environment on military operations and conflict;
- the impact of military conflict and operations on the environment;
- and the impact of environmental issues either directly or indirectly on international law and its relation to security interests.

Only relatively recently in international relations and security studies literature has the environment become of particular interest. It has received the most attention since the end of the Cold War, as theorists worked to consider what might next serve as origins of conflict in an international system largely shed of its primary ideologically-underpinned rifts of the previous four decades. The environment was not singled out without reason in this search for catalysts of post-Cold War conflict. The environmental movement was born at the height of the Cold War in the early sixties, and became engaged in earnest after the Stockholm Conference of 1972 and the publication of *Limits to Growth* (which addressed the carrying capacity of the natural environment in relation to population growth) around that same time. Growing awareness and activism over environmental problems set the stage for international negotiations to address them. These negotiations themselves became in part a proxy struggle of the Cold War, a public relations effort by the superpowers to demonstrate leadership on issues important to second and third tier nations

(especially post-colonial nations struggling to feed expanding populations and develop nascent economies), whose favor they curried for support on other issues of importance.

With international attention on issues of environmental concern, and mounting scientific evidence of the severity of problems provided by improved technology (ozone studies by satellite for example), it stands to reason that the environment might possibly prove to be a source of contention. Even before it became clear that the Cold War was ending - prior to the fall of the Berlin Wall and the subsequent dissolution of the Soviet Union - the dynamics of international conflict began to shift from superpower tensions played out by proxy to 'low intensity' conflicts that demonstrated considerably more variables among their sources, and it was not at all illogical that environmental problems that had been steadily growing in attention would be identified as potential areas of concern. In a landmark effort to redefine security late in this conflict, Richard Ullman opened the window to environmental security perspectives when he offered that a national security threat might be considered to be an action or sequence of events that "threatens drastically and over a relatively brief span of time to degrade the quality of life for the inhabitants of a state, or threatens significantly to narrow the policy choices available to the government of a state or to private, nongovernmental entities (persons, groups, corporations) within a state."[5] Jessica Tuchman Matthews more directly introduced the environment as a source of security concern a few years later, noting that environmental problems transcend sovereign boundaries and that demands on natural resources and environmental degradation provided stressors to international relations. Tuchman Matthews counseled that negotiations needed to address scientific uncertainty and asserted that where nuclear fission dominated the military, geopolitical, psychological and social forces of the Cold War, the environment would be the driving force of the future of international security.[6]

From the origins of environmental security described above, the greatest attention within the security studies discipline consequently has been directed at the possibility that conflict might arise out of environmental problems. This theme has been developed by many authors, notably in depth by Tad Homer-Dixon in *Environment, Scarcity and Violence* (1999); it is the same underlying theme of Robert

[5] Richard H. Ullman, "Redefining Security," *International Security* 8, no. 1 (1983): 133.
[6] Jessica Tuchman Matthews, "Redefining Security," *Foreign Affairs* 68, no. 2 (1989).

Kaplan's widely received article on the 'coming anarchy' in *The Atlantic Monthly* (later a book that takes that phrase as its title). Compendiums such as *Environment and Security: Discourses and Practices* edited by Miriam Lowi and Brian Shaw (2000), *The Environment, Foreign Relations, and U.S. Foreign Policy* edited by Paul Harris (2001), and *The Geopolitics Reader* edited by Gearoid O'Tuathail, Simon Dalby and Paul Routledge (1999) provide numerous perspectives on the possibility that environmental issues might inspire political discord and lead potentially to conflict. Environmental changes (natural or anthropogenically induced) can alter the quantity or distribution of natural resources. International environmental negotiations over the transport of water- and airborne pollutants and regarding the delicate topic of hazardous waste disposal, demonstrate the potential for environmental insults to contribute to cross-border tensions. Where extant differences such as race, ethnicity or religion already pose potential security problems, environmental problems might prove flashpoints to conflict; similarly, environmental problems might disrupt otherwise stable situations and allow other (exacerbating) differences to arise. Conflicts in the Philippines and in Chiapas, Mexico were linked by Homer-Dixon to this scenario: degradation of agricultural lands was made worse by political and ethnic divisions, led to forced migrations and eventually to the recruitment of disaffected persons by separatist rebel movements. Whether conflicts arise because of environmental change or environmental insult (degradation or pollution with attendant *responsibility*), they represent the upset of sustainable environmental situations in circumstances that lack institutional brakes, and that suffer in addition from other socio-political fractures that push environmental problems beyond peaceful resolution. An important conclusion drawn by theorists thus far – and the reason that environmental security has languished somewhat as a sidebar of security studies – is that absent these additional exacerbating factors in situations described above, it is questionable whether conflict would be the end result of environmental problems.

A more traditional geopolitical view of environmental security concerns the ownership and distribution of resources of intrinsic economic or strategic value. The *Resource Wars* described by Thomas Klare (2002) occupy this conflict-oriented branch of environmental security, and asserts that pending scarcity of resources such as oil and water dictates the need for security policies which protect access to these resources. Klare's thesis is arguably in play at the present time: it is hard to ignore the importance of fossil

fuels to the economies of industrial nations, and the part that access to steady supplies may have represented in recent Middle East / Southwest Asia conflicts. Security studies theorists who include economic security among the concerns of national security would logically focus on issues that involved environmental resource availability, but an additional consideration would relate to environmentally-based shocks to economies (droughts to agricultural economies for example, or floods and storm surges that devastate coastal regions such as happened during the Indonesian tsunami in 2004 and that occurs regularly in typhoon- and hurricane-prone regions). Faced with catastrophic economic failure or the inability to support populations, it is not inconceivable that states would strike out to gain the resources needed to stabilize their internal situations. From the opposing point of view from both a resource availability standpoint and with respect to environmental change, degradation or insult as described above, environmental issues have been investigated as possible means to cooperation by seeking proactive rather than reactive stances to environmental problems as described in *Environmental Peacemaking* (2003) by Ken Conca and Geoffrey Dabelko, a publication of the Environmental Change and Security Project of which Dabelko is the director. This compendium looks at six initiatives where environmental problems might serve as the catalyst for cooperation rather than conflict. A similar theme is voiced by Harold Bidlack, in *Swords as Plowshares: The Military's Environmental Role* (1996), which considers the use of military assets to address the humanitarian disasters of environmental catastrophe as a matter of operational doctrine rather than in the *ad hoc* way it is currently employed.

Another aspect of environmental security considers the affects of conflict and military operations on the natural environment. This spans a wide spectrum, from the physical degradation of the environment that occurs through the use of armaments in hostilities, to less obvious environmental impacts that result from peacetime military operations and training that pollutes and degrades the natural environment through fossil fuel use and by operating in sensitive ecosystems, to even more nuanced impacts that arise through the utilization of natural resources for the production of military goods by industry. In *Environmental Impacts of Military Activity* (1996) Derek Coronado discusses the environmental costs of military security as a matter of resource use, weapons testing, and toxic chemical and radioactive substance use. Exposés that occur sporadically in the media over the harmful effects of radioactive residues from depleted uranium

bullets demonstrate this aspect of the environmental costs of military operations; similarly, the disposal of military radioactive materials in the oceans by the Soviet Union continues to pollute the marine environment; to complete the nuclear trifecta – although thankfully never realized - an ongoing concern throughout the Cold War was the prospect of nuclear winter: the possibility that atomic blasts would pulverize enough dust and eject it into the atmosphere and subsequently trigger atmospheric cooling through an effect similar to one observed during volcanic eruptions in which solar rays cannot easily penetrate the volcanic dust.

Certainly many examples of the way that military operations impact the environment may be cited away from the nuclear field. Some subjects that fall in this category are ongoing controversies related to military operations; aspects of a topic that will figure centrally in the third case study of this dissertation – the impact of military sonars on marine life – fit squarely in this subdivision of environmental security. There are also many examples of deliberate alterations of the natural environment for military purposes – sometimes known as ecocide – which include the use of chemical defoliants such as Agent Orange in Vietnam, the widespread use of DDT in World War II to control insects, and the intentional release of oil into the Arabian Gulf from offshore terminals to disrupt naval operations and to possibly threaten desalination plants of other states during the 1991 Gulf War. Although the torching of numerous oil wells by Iraqi forces as they withdrew from Kuwait as that conflict drew to a close was more likely immediately intended to deny access to the commodity, the atmospheric pollution that occurred was on a scale that was easily visible from space. Similar tactics in use during the present war in Iraq include destroying oil pipelines and attacking fuel convoys, and demonstrate that scorched earth campaigns and other tactics to deny the use of resources - and which also degrade the environment - span history at least from the Peloponnesian Wars (and likely earlier) when the Spartans razed Athenian agriculture right up to the present day. In some fashion when conflict is afoot, the environment is impacted.

In light of the central role of force in security studies, it stands to reason that aspects of environmental security which relate to either potential causes for conflict or that have manifested as a result of conflict or military operations would dominate the academic literature and perhaps occasionally resonate in public

media when graphic examples strike chords of concern. But interestingly enough, it is within another subdivision of environmental security that the catalysts that led to the intensive study of the environment emerged: the impact of the environment on military operations. In many respects, this aspect of environmental security is descriptive and historical – providing innumerable accounts of the ways in which the natural environment proved pivotal in the conduct of military campaigns: the Spanish Armada, Napoleon in Russia, the Western Front in World War I, the D-Day invasions at Normandy… Provide a time in history, and an example of environmental impacts on military operations can be trundled up from the dust of archives. For the pivotal way in which environmental variables turned military campaigns and the course of human events, it is appropriate that environmental security should set aside a subdivision for appropriate study, but another aspect of the impact of the environment on military operations makes this subdivision of even greater immediate importance to the field of international security studies than for its historical value.

Because the environment impacts military operations, militaries *undertake research to mitigate or take advantage of environmental parameters*. This relatively obvious observation is not quite as obvious as it may seem; many environmentalists have little or no idea of the volume of environmental research which owes its existence to scientific research conducted to satisfy military requirements. The manner in which the environment affects military operations is essentially a virgin area of security studies, with little prior research available for which to refer - and what is available written largely unawares that it pertains to the field. Papers that describe the impact of environmental variables on military operations are written in journals germane to the environmental science in question, or in journals that consider military history, strategy and operations; but from either perspective, in general what is written is undertaken with little awareness that the subjects in question are of interest to environmental security as an aspect of international relations and political science – and that at times become even more important when considered consiliently with other aspects of environmental security. The inherently cross-disciplinary nature of such topics makes this aspect of environmental security less accessible to specialists in either the environmental sciences or the political sciences, and serves as a natural starting point for explaining the importance of consilient viewpoints for the entire discipline of environmental security.

One final area bears consideration as a matter of environmental security – international law. Clearly not all forms of international law contain substantive environmental elements, nor do all areas of international environmental law impinge directly on security – although indirect links may often be forged because of the many subtle connections between resource use and pollution with military activities or through economic significance of environmental resources, etc. as a matter of security concerns. But in some instances, connections are clear and considerable and in important ways may be linked to other aspects of environmental security. The first case study of the present work reveals this relationship particularly well when it demonstrates that the United Nations Convention on the Law of the Sea (UNCLOS) – not considered by all parties to be an environmental treaty, yet arguably the most extensive environmental treaty on the books given the number of articles that provide for marine protections and enjoin parties to be good stewards of the marine environment – was essentially the end result of a process that began when environmental resources were identified as a byproduct of military investigations of the ocean environment. UNCLOS is widely considered the greatest success story of international law, with almost universal acceptance among states as signatories and containing many provisions that are considered common practices under international law by at least some who are not parties. Although nominally a treaty that pertains to peacetime activities, nevertheless it holds enormous implications for naval operations and for national security through definitions of territorial seas and exclusive economic zones, transit and innocent passage rights, and other duties and privileges of both military and commercial vessels operating on the world's oceans. When international environmental law impinges upon military activities, it has relevance to security studies and by association with environmental security; when international laws arise as a result of issues related to environmental security – even if it may be argued that treaties like UNCLOS should not be considered environmental law – they are also linked *de facto* to this sub discipline of security studies.

As a nascent sub discipline of security studies, environmental security still suffers from a lack of conceptual clarity. The current literature recognizes differences among topics that have been labeled 'environmental security,' but allows the concept to wallow by failing to delineate discrete internal divisions or to integrate the various elements into an overarching theory of environmental security. The tendency to

pigeonhole environmental security concepts narrowly to theories that posit the *potential* for environmentally-induced conflict – and disagreement over whether this is a legitimate and relevant perspective - ignores the enormous interconnectivity that does manifest between the environment and security concerns in other fashions; and, as result of the inability to conclusively link the environment with conflict, this is the primary cause of indecisiveness with respect to accepting environmental security readily as a sub discipline of security studies. The closest an author has come to comprehensively examine the field is the essay *Environmental Degradation and Security* by Terry Terriff (1997) in which he discusses the breadth of material that should be covered in a proposed course on the subject. But his effort, while endeavoring to round out the topics that have been raised under the environmental security rubric, does not include one of the most relevant connections of environment and security issues: the dedicated military effort to study the environment in order to reduce its effects on operations and on weapons platforms and systems.

It is this facet of environmental security – the impact of the environment on military operations - with which this dissertation begins and then proceeds to link together environment-security concepts by demonstrating the connectivity of environmental security issues among the subdivisions the author suggests earlier as a logical way to break down matters of environmental security in order to more logically link them where appropriate in analyzing a particular set of issues. This interdependence of environment and security issues across potential subdivisions of the field leads the author to define environmental security matters rather simply as instances where the natural environment impacts or influences any of the referent levels of security. Defining environmental security this way is neither tautological nor so amorphous as to render it conceptually ineffective. Instead, it challenges the scholar to examine situations more holistically and to avoid reductionist tendencies that strip explanatory value by confining perspective to so tight a field of view as to fail to provide any insight.

The Ocean Environment and National Security

Although the United States spans more than three thousand miles and the width of the North American continent, it is a maritime nation and its national security has always been connected in some fashion to the oceans. The Atlantic Ocean and the Gulf of Mexico form lengthy segments of the international boundaries of the U.S. on its eastern and southern borders, and the Pacific Ocean and Arctic Ocean serve similar roles to the west and north. America's remaining contiguous borders are shared with only two other states: Canada and Mexico. Threats to the physical integrity of the U.S. could – and occasionally through its history did – emanate from north and south of the continental U.S. border, but threats from any other state or entity had to cross an ocean. Early in its history, foreign involvement in American wars was dependent on transport and supply by sea, and sea power played pivotal roles in each of the major conflicts on American soil. For the better part of the last century foreign incursions or attack theoretically has been possible by air forces, but aside from the relatively few states that possessed long range ballistic missiles this means of access was fairly limited across vast stretches of sea beyond the tactical range of most aircraft; that leaves the oceans as both barrier to and conveyor of threats to homeland U.S. national security interests.

If the U.S. were entirely insular, with no national interests on (or under) the seas or in locations overseas, then coastal defenses and a Coast Guard might have sufficed to protect U.S. national security through the course of its history. But U.S. interests have long ranged beyond the water's edge, as a matter of economics through fisheries and trade and through the necessary transport of natural resources required to drive the national economy. To protect these interests on the seas and overseas by maintaining open sea lines of communication and by projecting power to far flung places around the globe, the United States Navy has existed for essentially the same period of time as the U.S. as a state on the international stage. Dependent as it has been upon naval power throughout the course of its history, the United States played an integral role in the development of technologies to maintain its naval strength. When those technological advancements necessitated a greater understanding of the marine environment for naval superiority, the U.S. Navy remained in the vanguard by leveraging the nascent field of ocean science. This longstanding

relationship has served to solve some challenges to national security in the oceans, but opened the door to altogether new ones.

Why is ocean science important to national security? In one sense it is a question already answered by the impetus to develop the field as a science: to mitigate the impact of the marine operating environment on military forces and weapon systems. But that is not the whole story. The securitization of environmental parameters (making them the subject of investigation for their importance to security-related research) in the oceans to address naval challenges such as antisubmarine warfare often leads to the discovery of environmental properties, resources, and relationships that in turn represent new considerations from a security perspective. This does not necessarily take place in the "black" world of secret research. The development of technologies and techniques in oceanographic research are often of a dual-use nature, and facilitate further non-security related research and discovery that may itself – because of the nature or perhaps the geographic location of the research - feed back into the security realm.

New environment-security relationships made evident in this process are complex in part because of the oblique fashion in which they can come to light, often divorced entirely from the initial intent of the research that led to their clarification…a discontinuity that contributed in the past to an apparent inability to predict or anticipate their evolution. To demonstrate the types of relationships I am describing, this dissertation will examine four case studies in which marine environmental parameters were securitized to address military concerns, and which ultimately led to a host of new environmental security considerations…issues that in some cases dwarfed the catalysts that precipitated their discovery. Some of these expanded areas of interest are readily assessable as security related while others must be looked at with a broader appreciation for what constitutes a security issue or concern, and demonstrate the give and take of the environmental security debate within the discipline of security studies and the need for consilient interdisciplinary analysis and interpretation. Nevertheless, the scope of the issues raised and the sheer import of many of them make clear how critical ocean science has been and will continue to be to the national security in the United States.

The primary impetus to the rapid development of oceanography during its 20th century glory days as a science is without a doubt the submarine. The first case study focuses on the fundamental changes that occurred when naval warfare became truly three-dimensional. Prosecuting submarines was feasible principally through the transmission of underwater sound, actively by sonar to echolocate targets and passively by listening hydrophones and triangulation. The scope of oceanographic efforts in the pursuit of the submarine opened all of the oceanographic disciplines (physical, chemical, biological, and geological oceanography) to increased investment, research effort and – importantly – to integration. The fluid environment of the ocean may support different subdivisions of oceanography, but these divisions are artificially constructed simplifications and vestigial remnants of traditional scientific disciplines that found marine applications when the oceans were securitized. In truth the science of each discipline of oceanography blends so smoothly into the concerns of the other that often it must be asked where a line of inquiry first began. The breadth of discoveries and knowledge achieved by this monumental security effort in the oceans is staggering, and the corollary impacts upon security and national interests equally so. Twentieth-century oceanography was fundamentally a security-based endeavor to reduce the opacity of the oceans to antisubmarine warfare in WWI, WWII and the Cold War, and harness that opacity for offensive submarine operations, along with a host of other security based (naval) concerns. But the technological developments and scientific discoveries that took place along the way changed security conceptions irrevocably, inspired massive overhauls of international law, and have set the stage for future changes as will be investigated in the third and fourth case studies of *Beyond the Water's Edge*.

The identification of oceanography as a science important to national security is not unique to this dissertation. A number of articles and books are referenced extensively throughout for the facets of environment-science-security themes that they develop. Some of these works bear specific mention here for the particular value they hold for further reading on these important relationships. *New York Times* science writer William Broad's *The Universe Below* (1997) is an informative as well as entertaining read which recounts many important events in the exploration of the oceans which held importance to naval operations. Naval historian Gary Weir recounts the symbiotic development of oceanography with naval pursuits as the effort of a small epistemic community whose mutual interests were served by the

development of the science from WWI to the early 1960s in *An Ocean In Common: American Naval Officers, Scientists, and the Ocean Environment* (2001). Sherry Sontag and Christopher Drew reveal a number of important events that took place when submarine warfare rose to its peak during the Cold War and when deep submergence technologies pushed both the limits of ocean science as part of the undersea battle that was waged. To this day former submariners shake their heads and refuse to discuss some of the details that Sontag and Drew describe in *Blind Man's Bluff* (1998).

Articles in military and science journals also provide a great deal of insight into events that witnessed the application of ocean science to naval challenges. Ed Whitman, the former technical Director for the Office of the Oceanographer of the Navy provides some first-hand insights into one of the more critical developments of the Cold War in *SOSUS: The "Secret Weapon" of Undersea Surveillance* (2005) in an edition of *Undersea Warfare*, the professional publication of the U.S. Submarine Force. An important account of the development of oceanography as a naval science is Roger Revelle's reminiscence in *The Age of Innocence and War in Oceanography* (1969). Few academic treatises could be found that address the themes of this case study, but one which touched on issues germane to the subject was written by Jacob Hamlin, in *Oceanography and International Cooperation During the Early Cold War* (2001). In this dissertation, Hamlin examined scientific interdependence based upon international cooperation in the oceans in the International Geophysical Year and the International Indian Ocean Expedition in the late 1950s and early 1960s. He attributes the growth of oceanography to national security concerns (particularly in the United States), but remains focused on the early Cold War period. He emphasized the cooperative relationships of civil-military leaders and government officials, and the translation of that cooperative framework internationally through joint ocean studies. No other dissertations were encountered that treated oceanography as a matter of national security and environmental security in particular, nor were any works encountered that spanned the timeframe of either this case study or the four studies of this present work in the aggregate.

To investigate whether the relationships observed in the 20th Century had antecedents that demonstrated more enduring principles at work, the second case of *Beyond the Water's Edge* considers the earliest days

of ocean science in the United States under the leadership of U.S. Navy Lieutenant Matthew Fontaine Maury. Maury's efforts to incorporate environmental information into voyage planning improved the safety and efficiency of navigation to such a degree that the transition from sail to steam powered ocean vessels probably took place later in the 19th century than it might have otherwise. Early steam vessels were rather unsafe and unreliable on the open ocean. Forced to compete with more efficient sailing vessels, improvements had to be made in the construction of steam engines and steam-powered vessels that likely made the eventual transition from sail to steam a safer one. But Lieutenant Maury's efforts to unlock the secrets of the oceans led to even more fundamental changes that entrained enormous security implications along the way. Dedicated research cruises dispatched by Maury sounded the oceans for the first time on a basin-wide scale. The discovery of a 'telegraphic plateau' – essentially an error on Maury's part, but an honest one based upon the density of available data – led directly to the first successful submarine communications cable between North America and Europe. The eventual spread of such cables both enormously impacted security considerations and provided some of the initial stirrings for more comprehensive looks at international maritime law.

If only for the contributions noted above, Matthew Fontaine Maury's legacy would be assured, but he is widely credited for what is purported to be the first major international conference to address the environment. The 1853 Brussels Conference brought together major ocean powers in a joint venture of data collection to benefit all seagoing nations, regardless of their differences elsewhere. As an institutional measure of engagement, it may have been a harbinger of an entire field of international relations and security studies: liberal institutionalism. Maury also was responsible – however unlikely it was that he ever intended for such an action to transpire – for perhaps the first use of geophysical information to serve as targeting information when it was used to support a strategy of *guerre de course* by the Confederate Navy in the Civil War. When he "went South" in this war, Maury put his oceanographic experience to use in developing one of the deadliest naval weapons in history: the underwater mine. Matthew Fontaine Maury's work at the intersection of oceanography and security are legion; his researches form the basis for charts still in use by the U.S. Navy and his theories on ocean currents serve as the basis for modeling efforts that serve search and rescue strategies into the present.

Matthew Fontaine Maury's life and contributions to oceanographic science are the subjects of many biographies, predominantly written in the middle of the 20th century when Maury's reputation was rehabilitated after an initial period when he fell out of favor as a result of his choice to join the Confederacy in the Civil War. *Matthew Fontaine Maury: Pathfinder of the Seas* by Charles Lewis (1927), *Life and Letters of Matthew Fontaine Maury* by Jacqueline Amber Caskie (1928), *The Pathfinder of the Seas: The Life of Matthew Fontaine Maury* by John Wayland (1930), *Matthew Fontaine Maury: Trailmaker of the Seas* by Hildegard Hawthorne (1943), *Seeker of Seaways: A Life of Matthew Fontaine Maury, Pioneer Oceanographer* by Janice Beaty (1963), and *Matthew Fontaine Maury: Scientist of the Sea* by Frances Leigh Williams (1963) are but some of the many works on Maury's life that provide important details about his career as a naval oceanographer. Maury was also the subject of a recent book by Chester Hearn, *Tracks in the Sea* (2002), which the author found of particular importance for references to the use of Maury's work by Captain Raphael Semmes of the Confederate Navy. Captain Semme's own *Memoirs of Service Afloat During the War Between the States* (1868) provided invaluable insights into how Maury's researches became of tactical value during his career as Captain of the Confederate raider *Alabama*. Most of the author's views on Maury stem directly from his original writings and not from the interpretations of these later historians – or in the case of Raphael Semmes *colleague* - though they certainly provided important perspective and were used extensively as references throughout this case study.

Each of these historical works sheds light on the value of Maury's research beyond the interests of the United States alone, and as the seminal work in the nascent discipline of oceanography, but none treat Maury's efforts from an environmental security framework that views these achievements through a lens of national security and international relations. Only one doctoral dissertation could be discovered related directly to Maury: *Science, Commerce and the Navy on the Seafaring Frontier (1842-1861) – The Role of Lieutenant M.F. Maury and the U.S. Naval Hydrographic Office in Naval Exploration, Commercial Expansion and Oceanography Before the Civil War* (1966), a history dissertation by Edward Towle that describes the impact of Maury's work on the spread of U.S. influence as a growing naval and commercial power during the middle of the 19th century. A doctoral dissertation by Helen Rozwadowski, *Fathoming*

the Ocean: Discovery and Exploration of the Deep Sea, 1840-1880 (1996), describes the development of ocean science in the middle of the 19th century, but interestingly as one inspired by a popular cultural fascination with the sea and as a collaborative between scientists, mariners and others with predominantly economic interests…and not as a security issue. Rozwadowski's follow-on ocean science book, *The Sea Knows No Boundaries: A Century of Marine Science Under ICES* (2002), also focuses on the civilian aspects of oceanography – predominantly fisheries – under the auspices of an early international organization, the International Council for the Exploration of the Seas.

The third case study of this dissertation affirms oceanography as a science wedded to security concerns when present day scenarios are considered. Once more the submarine presents a challenge to the United States Navy, but this time in the form of quieter modern diesel boats which operate in the geophysically complex and variable littoral waters off the coasts of the continents rather than in the reasonably homogenous (by comparison) waters of the open ocean. Sonar is again the method of choice for prosecuting these sharks of steel, but newly developed low-frequency active versions proffer improved detection ranges when passive methods which utilize the sound channel are no longer up to the task. The same physics and technology that underlies this approach to undersea warfare serves a civilian research goal of measuring temperature changes in the oceans in the search for signals of long term climate change. Both technologies become threatened by environmental opposition to their use over their potential to harm marine mammals and other marine life, a situation that becomes even more complicated when older versions of sonar – mid-frequency range sonars that have been in use for decades – demonstrate lethal impacts on marine mammals when they are used in littoral environments that have become the present day focus for antisubmarine warfare. Environmental resistance to the use of sonar in either its military or civilian forms runs a course through domestic legal channels in the United States; it then takes root in various forms of international opposition and raises the possibility that underwater sound might be treated as a transboundary environmental pollutant under international law, a development that could influence where and *how* navies operate.

A second critical contemporary issue is developed in the final case study of *Beyond the Water's Edge*. Another technology important to antisubmarine warfare for its capacity to measure the variability of the ocean environment which affects sonar propagation - the satellite altimeter – also demonstrates its relevance for climate research. This important scientific tool becomes imperiled because of bureaucratic decisions made at a time when antisubmarine warfare had waned as a priority after the Cold War. A tandem effect is revealed in concert with what is observed in the third case - with growing evidence that climate change may in fact hold security implications in the not-so-distant future, the methods and instruments with perhaps the most significance for measuring the phenomena in the oceans (especially on the mesoscale in areas particularly important to ocean circulation and that potentially represent the canaries in the coal mine for detecting signals of abrupt climate change) have both become imperiled - one by legal entanglement and the other by programmatic lag times for developing alternatives and competing budget priorities. Present day interactions between ocean science and security concerns are both complex and constantly in flux, but not at all surprising after the first two case studies provide insights into the relationships which underpin them.

Most of the research that supports the contemporary third and fourth case studies comes from scientific journals that describe the techniques, technologies, and phenomena in question, and from present day media reports regarding the ongoing controversies described above. A great deal of information was available on the Internet as support materials for Environmental Impact Statements drafted by the United States Navy when seeking authorizations to conduct research and operations regarding both low frequency and mid-frequency range sonars, and from environmental groups that oppose both the Navy's use of sonar and the civil oceanographic version of the technology that is known as acoustic tomography. A number of reports published by the National Academy of Science provide outstanding surveys of research related both to underwater sound and marine mammals, as well as to theories of climate change in both long term and abrupt forms. The author found *Climate Crash: Abrupt Climate Change and What It Means to Our Future* by John Cox (2005) particularly insightful in revealing the intricacies of a difficult subject, and owes an equal debt to Elena McCarthy's *International Regulation of Underwater Sound: Establishing Rules and Standards to Address Ocean Noise Pollution* (2004) for helping to sort through many of the details

regarding the possibility that underwater sound – including that produced by military sonars – might become subject to treatment as transboundary pollution. The bulk of the information related to satellite altimetry is drawn from evolving scientific literature on oceanography and climate change, and from news accounts and congressional reports regarding the oversight of environmental remote sensing strategies. In addition, for the contemporary case studies the author draws extensively on his own experience as a naval oceanographer, and credits many of the insights drawn in this look at present day relationships between oceanography and security from innumerable conversations over his career with predecessors and colleagues regarding issues germane to those under consideration.

Contributions

The four case studies of *Beyond the Water's Edge* span virtually the entire history of ocean science, and it is the author's intention and sincere hope that readers gain an appreciation for the enormous significance of oceanography to matters of national security and to other subjects of national and international importance. The cases presented here and the riveting stories they relate bring to light some of the efforts of the pioneers of ocean science - men and women who sought to reveal the secrets of the oceans in the defense of and service to their nation, but in the process shed light on a world largely cloaked in darkness. Ocean science began as a discipline that supported and was supported by naval interests, and its historical growth parallels the growth in importance of environmental parameters as matters of security. Oceanography's future also appears largely connected to security interests – in both 'traditional' ways related to military threats and non-traditional threats that may result from environmental challenges such as climate change if and when it becomes established as a matter of security concern. In a sense, this will represent a return to its roots – Maury's research was related to ocean challenges that affected all maritime operations, not only operations in which naval forces opposed each other.

While this study proposes that oceanography began as, developed as and remains predominantly a naval science, it would be wrong to assert that all facets of ocean science are undertaken in support of security interests; indeed many efforts deliberately seek to distance themselves from both security interests and

coffers. But in comparison to the large scale efforts underway in the field – which dominate both funding and attention – such efforts provide rich texture to the science but do not define its direction. Much remains to be seen about how present day oceanographic efforts will extend beyond areas that inform naval interests, but it is unlikely that a break from security-related research will happen at any point soon for ocean science. The United States Navy continues to be the pre-eminent sponsor of ocean research worldwide, supporting many areas of applied oceanography but also the basic exploratory research that underpins later developments. It is true that public interest in the oceans is continually stimulated by the well documented discoveries of natural phenomena and historical significance; but while it may remain less well-known, ocean exploration is undeniably facilitated by naval technologies and some of its most famous personalities are alumni of naval oceanography. There is nothing untoward with such relationships; mankind owes many advances in areas of science, technology and medicine to the mother of inventions: necessity. It just happens that mankind also has a peculiar and persistent habit of threatening one another, such that necessity itself has a source: security.

The present work attempts to bring a very large volume of evidence together to demonstrate relationships that might otherwise escape attention or understanding because of their scope and because of their interdisciplinary nature which sometimes makes them less than intuitive. In the process, as a work of social science it also endeavors to add to the body of security studies literature through its efforts to investigate important aspects of environmental security. In this regard while the author hopes that the cases stimulate other ideas for additional research, four areas are highlighted as specific contributions to security studies from the present effort. First: as a matter of security studies, environmental security demonstrates relevance beyond the potential for matters of the environment to *incite* conflict; and through the number of environment-security interactions investigated in the present work the author asserts that environmental impacts on military operations are more central to the discipline of environmental security studies than heretofore considered. Second: environment-security matters are not necessarily first order cause-and-effect phenomena, and a more consilient interdisciplinary viewpoint of environmental security appears necessary to understand how relationships develop through complex feedbacks and to appreciate how significant matters of the environment are to international security studies. Third: the case studies

presented support the hypothesis that securitization of environmental parameters is an important factor for supporting research into otherwise formidable areas that might remain beyond understanding without a security imperative; research into these otherwise neglected areas (often) engenders additional security considerations which might otherwise not have developed or been revealed. And logically as a fourth contribution, even if a rather obvious statement: when consilient viewpoints afford a better understanding of the manner in which ocean science illuminates, underpins and expands environment-security relationships, they will provide critical insights to policy makers responsible for the oversight of oceanographic research in support of national security and other national interests of the United States. The author's intent was to develop the cases that follow in a fashion that informs the reader about the importance of interdisciplinary understanding, but does not require extensive personal background in the fields under consideration to comprehend either the overall subject matter or individual elements in their esoteric minutiae. On a scientific, political and historical journey of exploration where matters of the environment and security intersect throughout the oceans, the reader is invited to voyage *Beyond the Water's Edge*.

ΨΨΨ ΨΨΨ

ΨΨΨ Chapter 2 The Ocean Environment and the Third Dimension of Naval Warfare ΨΨΨ

The archives of naval warfare are interspersed with battles and campaigns in which the outcomes of encounters were often unpredictable, in that so many variables presented challenges to combat at sea. One of naval history's most famous figures, the British Admiral Horatio Nelson, remonstrated his captains in his battle orders that while they could not anticipate all contingencies, they must be prepared for the unexpected, for "Something must be left to chance; nothing is sure in a Sea Fight beyond all others."[1] Undeniably doctrine and tactics played an important role in naval strategy, but strict adherence could prove disastrous if commanders did not grasp "on the fly" the changes required to meet and counter innovations of adversaries. Of these, warship design, propulsion and armament dominated - since they determined mobility and firepower and victory at sea was often a tale of "getting there the firstest with the mostest."[2] The rapid technological expansion that accompanied the industrial revolution of the 18th and 19th centuries accelerated the pace at which changes were introduced in naval warfare. During this dynamic timeframe smoothbore cannon and iron shot gave way to rifled guns and exploding shells, and the dominance of the wooden warship faded into history once the first ironclads appeared on the scene. These hybrid warships were soon followed by vessels designed from inception with hulls of steel and modern armor and armaments that dramatically altered time honored tactics, logistics and broader strategies of naval warfare. Small modern navies suddenly posed inordinate challenges to larger yet technologically obsolete flees. Yet despite the tactical and strategic complexity and challenges that these rapidly changing characteristics of naval warships posed, there remained a critical way that the already multivariate environment of naval warfare would become substantially even more complex...through the addition of an entire geospatial dimension.

The history of combat at sea spans millennia, but throughout the vast majority of this continuum the dynamic time-space-firepower problem inherent to naval encounters pertained to warships that sailed the

[1] Quoted in A. T. Mahan, *The Life of Nelson: The Embodiment of the Sea Power of Great Britain*, II vols., vol. II (Cambridge: John Wilson and Son, 1897), 344.
[2] The gist of this aphorism of warfare is generally attributed to General Nathan Bedford Forrest of the Confederate States Army in the U.S. Civil War, but it has appeared in many forms as a truism for a subject so dependent on considerations of time & space, and in which the ultimate arbiter – once those first two dynamics have been determined - is force.

surface of the world oceans. It has been only within the last few centuries that this archetype of surface supremacy was challenged, and undersea warfare emerged to alter the doctrine of naval warfare – and to complicate a "Sea Fight" in ways Nelson could not have imagined. In doing so it stretched the requirements and constraints of achieving superiority at sea beyond the realm of practiced naval tactics and theory, beyond the defined engineering arena of naval architecture and armament, and beyond the extant understanding of time-space dominance of the geographic maritime battlespace…to the little understood, largely undefined and barely investigated domain of the geophysical battlespace. Expansion of military interest to this scientific dimension was necessary to address the new submarine threat unleashed upon navies and merchant fleets of the world, and to counter the somewhat lesser yet still significant concurrent threat posed by underwater mines and other facets of undersea warfare. Constructing capable means to defend against and destroy such threats required the rapid development of ocean science and technology, the creation of cross-disciplinary expertise, and an intimate relationship between academic research and military application heretofore unseen in naval warfare. The partnerships formed over the following decades bred successful methods against the submarine and other undersea warfare threats, but this coordinated effort to make transparent the opaque ocean environment led to security ramifications that would have been difficult to imagine as the collaborative necessity first surfaced in earnest in the turbulent days of World War I.

Dive, Dive, Dive…from Genteel to General Warfare at Sea

Inasmuch as it is a subset of the rather uncivilized activity of warfare, the concept of utilizing undersea vehicles and weapons in naval combat was in its infancy the subject of criticism that bore a remarkably civilized tone. The notion of employing vessels barely visible above the waterline to attack other ships was considered not very sporting. It was thought of as somewhat dastardly and sneaky…rather interesting when one considers that in such a bloody arena as warfare, at the end of the day the defeat of an enemy's military forces by one's own forces – according to military strategists of the 18th through early 20th

centuries - was the penultimate objective prior to enemy capitulation.[3] Largely viewed as unchivalrous, underwater warfare was also seen as an affront to international norms; an American admiral in the United States Civil War threatened to hang the crew of a submerged Confederate vessel that attacked his flagship "for using an engine of war not recognized by civilized nations."[4] Robert Fulton, the inventor of the first practical steamboat and one of the earliest designers of submarines, saw the need for commissions for submarine crews because "fire Ships or other unusual means of destroying Navies are Considered Contrary to the Laws of war, And persons taken in Such enterprise are Liable to Suffer death."[5] Naval warfare was a more deliberate and honorable activity, noble even in its ferocity.

For more than two centuries prior to the 1800s line-of-battle sailing vessels were the sovereigns of the seas. In a seafight they squared off broadside to broadside and endeavored to disembowel each other with cannon fire as sailors fought hand-to-hand in boarding parties, and marine sharpshooters poured in fire from the rigging and from fighting tops in the masts. In such close quarters the loser was the one who "struck" his colors; and as was the case in the famous battle between the American *Bonhomme Richard* and the British *Serapis*, the winner was not necessarily the vessel that remained afloat! This was "the way it was done" and the naval doctrine that grew from such encounters became so restrictive that a British Admiral was executed after an encounter with the French Fleet for breaking the conventions of the line-of-battle.[6] Nelson, easily the most famous naval commander of his era, gained his fame and some of his greatest victories by defying the conventional dogma of doctrine, as did his contemporary Napoleon while

[3] Respected military strategists such as Antoine Jomini and Carl von Clausewitz emphasized the enemy's forces as the target or 'center of gravity' in war. The key to victory was to smash the enemy in decisive battle. While these two military thinkers were considered more to be experts in land warfare, the strategist most associated with naval warfare – the American Alfred Thayer Mahan – was a similar proponent of deliberate engagement with the enemy's forces; through his review of major naval campaigns throughout history, he emphasized the defeat of enemy fleets as a key element of sea power. Specific objections to the use of submarines in warfare will be addressed directly, but many references demonstrate the disdain with which they were held, including the British assessment that they were "underwater, underhand, and damned un-English" as related in Richard Compton-Hall, *Submarine Boats: The Beginnings of Underwater Warfare* (New York: Arco Publishing, Inc., 1984).
[4] Quoted in Alex Roland, *Underwater Warfare in the Age of Sail* (Bloomington: Indiana University Press, 1978), 162.
[5] *Caps* sic. Quoted in Ibid., 93.
[6] Helmut Pemsel, *A History of War at Sea* (Annapolis: Naval Institute Press, 1989), 67. When British Admiral John Byng was executed for his failure against the French at Minorca, Voltaire observed dryly that, "Dans ce pays-ci, il est bon de tuer de temps en temps un admiral pour encourager les autres." *In this country we find it pays to shoot an admiral from time to time to encourage the others.*

waging a new style of land warfare. But even then the naval tactics Nelson employed still adhered to the basic tenets of converging with the enemy and hammering away at close quarters. Although this won him victories, it cost Nelson his life at Trafalgar. A French sharpshooter on the mizzen top of *Redoudtable* struck him down on the deck of *HMS Victory* amidst the chaos and smoke of battle fought at such short range that the yardarms of the two combatants became entangled – the type of fight that epitomized contemporary naval warfare and that forms the lasting image of combat in the Era of Sail.[7]

Even once the august line-of-battle sailing vessels were augmented with auxiliary steam power toward the middle of the 19th century, and later when sails were removed altogether, naval warfare was still akin to a boxing match. Combatants closed, assessed – and possibly addressed or "spoke" – each other, and then slugged it out until one limped away, surrendered altogether, or joined other vanquished vessels in Davey Jones's Locker. More advanced naval guns allowed engagements at ranges beyond the point where boarding parties might swarm from deck to deck, although this possibility remained a constant and cutlasses did not disappear from the inventories of some warships until the time of the First World War![8] Nevertheless, vessels remained in sight of one another, and throughout the fight the pugilists engaged in combat as if toe-to-toe, following the Marquess of Queensbury Rules of the metaphor. In contrast to this open if brutal method of battle, whether they were manned or unmanned underwater devices that relied on stealth were denigrated as "infernal machines" that violated some code among combatants, an underhanded tactic that did not conform to *honorable* warfare among civilized men.[9] Perhaps in part because of this "unchivalrous" aspect of its nature, and certainly in no small respects because of the technical challenges such innovations presented, undersea warfare – essentially the employment of early versions of submarine-like vessels as well as the use of underwater mines, or "torpedoes" as they were first known - took time to implant among accepted doctrines of naval strategy. All the same necessity eventually led to the adoption of undersea warfare in the latter half of the 19th century as a primary element of the naval strategy employed by a combatant that was less endowed with capital ships than its opponent, yet still capable

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7 Mahan, *The Life of Nelson: The Embodiment of the Sea Power of Great Britain*, 386-390.
8 Gerald Weland, *A Collector's Guide to Swords, Daggers & Cutlasses* (London: Chartwell Books, Inc., 2001), 63.
9 "A Rebel Infernal Machine," *Harper's Weekly*, November 2, 1861, 701; Roland, *Underwater Warfare in the Age of Sail*, 89-105.

enough to acquire or engineer the technologies intrinsic to such novel undersea weapons. Nowhere a match conventionally for the Union Navy it opposed, the Confederate States Navy relied heavily upon undersea warfare to devastating effect during the United States Civil War.

The first vessels labeled "submarines" were not true submersibles, but instead were vessels with very little of their displacement visible above the surface. If they submerged, they were never very far beneath the surface or down for very long periods, and anything but gross navigation was something that required surface references until much later in the submarine's development. The potency of these underwater craft was not in their ostensible firepower – the earliest recorded attempt of an attack involved an effort to drill a hole in an enemy vessel to plant an explosive (it failed) – but rather in their stealth. With a cautious approach on an enemy that was not expecting or was unprepared to defend against such an assault, an early "submarine" might strike its target with a spar torpedo - the tactic employed for the first successful attack on a warship by *CSS Hunley* against *USS Housatonic* in the United States Civil War. Despite its sleek tubular design and "submerged" mode of attack, it is not really appropriate to deem *Hunley* a submarine as current readers would perceive such craft; it remained at or very near the surface for navigation and oxygen supply when it went to "sea", during its attack run, and while it attempted escape…all in the confines of the harbor at Charleston, South Carolina. [10]

However semantically independent it may have been from a true submarine, *Hunley* and its brethren (known collectively as *Davids*, as in *David* versus *Goliath*) – were not the only underwater weapons utilized by Southern forces against the Union. Rounding out the Confederate undersea arsenal -and demonstrating its ingenuity against a stronger naval foe that attempted to construct a constricting blockade of it ports according to a suggestively titled "Anaconda Plan" - the South employed innovative naval mines. These were the "torpedoes" of Admiral David Glasgow Farragut's famous "Damn the torpedoes!" battle cry during the naval assault of Mobile, weapons that inflicted heavy damage to the Union fleet and soon became part of international naval arsenals after their effectiveness was proved operationally by the Confederacy. Whatever disdain Union officers demonstrated for the "underhanded" undersea tactics

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[10] Robert Hutchinson, *Submarines: War Beneath the Waves* (New York: Harper Collins, 2001), 6-13; Roland, *Underwater Warfare in the Age of Sail*, 75-88.

employed against them, they were not so foolish or ignorant to overlook their import in the annals of naval warfare. "Among the many inventions with which I have been familiar, I have seen none which have acted so perfectly at first trial," reported Rear Admiral John Dahlgren to Assistant Secretary of the Navy Gustavus Fox, merging the two undersea technologies in his assessment since the "submarine" was essentially a delivery platform for an underwater torpedo. "The secrecy, rapidity of movement, control of direction, and precise explosion indicate, I think, the introduction of the torpedo element as a means of certain warfare. It can be ignored no longer."[11]

Submarines in a modern sense appeared late in the 19th century; the initial models constructed by the Irish expatriate John Holland in America around 1880 demonstrated underwater endurance to an extent that made the platforms legitimate submersibles. The United States Navy constructed a series of more advanced *Holland* boats (with diving capability, as opposed to submerging which was really controlled sinking) in the early 1900s. The British and French also experimented with and built submarines at the turn of the century. The French constructed the *Narval* and later the *Gustav Zede*, a vessel which proved the effectiveness of stealth tactics during sea trials when it effectively "sank" the French fleet near Marseilles in 1901. The British adopted the *Holland* boat model – interestingly enough, for John Holland was a Fenian who strongly opposed Britain and had designed his original craft to *sink the British fleet* – rather than conducting their own independent design and construction. Following the obvious example set by the *Hunley*, and vicariously benefiting from the experience of the French tactical exercises, Britain understood what the submarine was capable of accomplishing, but viewed the platform primarily as a defensive asset. While submarine construction was already well underway in these three navies, the fateful development of this new platform was that accomplished independently by Germany. Locked in a capital ship building race with Great Britain, the German High Command commenced its submarine construction program later than other countries, but saw the submarine almost immediately as an offensive weapon and began a concerted effort to develop its "overseas" submarine fleet as the first decade of the 20th century drew to a close. [12]

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11 Quoted in Roland, *Underwater Warfare in the Age of Sail*, 162-163.
12 Michael Gunton, *Submarines at War: A History of Undersea Warfare from the American Revolution to the Cold War* (New York: Carroll & Graf Publishers, 2003), 14-16.

The development that made the submarine an undeniable threat to surface vessels was that of the independent-running torpedo. It offered exponentially greater opportunities to inflict damage than earlier weapons. The spar torpedo such as that used by *CSS Hunley* was literally a bomb on a stick, an explosive device fixed at the end of a movable pole that was rotated away from the delivery vessel and thrust into the side of a target and triggered as the attacker made its retreat. The resulting explosion could do as much damage to the delivery vessel as it did to the target. Although *Hunley*'s fate was not known for more than a century after the attack on *Housatonic*, what was evident was that she did not return from her mission – not a very comforting endorsement of such a tactic for those that might follow in her wake.[13] The first effective modern torpedo (as opposed to the original "torpedoes" which comprised a class of underwater devices now more commonly classified as mines) was the Whitehead torpedo, a sleek tubular self-propelled weapon developed in 1866 by a British engineer, and first employed from surface vessels known as torpedo boats. Later models of this device achieved gyroscope-stabilized submerged runs and possessed contact or magnetic influence detonation capability, but at some 22 feet in length and armed with 500 pounds of TNT it was a weapon that an early submarine could carry only in limited quantities.[14]

Torpedoes offered the submarine the greatest stealth in the vicinity of its target; while submerged at periscope depth a firing solution could be determined and the first indication a victim might have that it was under attack was the telltale wake of a surface running torpedo. Against warships – that might shoot back – this was obviously a preferable mode of attack; however, against unarmed merchant vessels that were either enemy flagged or carrying contraband and subject to targeting by combatants, it was not prudent to waste a "fish." Instead the submarine could surface and sink its prey with fire from its topside guns. Whereas it was economical to husband torpedoes and sink unarmed vessels in this fashion, it was not without danger. Submerging was a process that took some minutes, and while the submarine remained on

[13] *CSS Hunley* was raised with great fanfare from the bottom of Charleston harbor in August, 2000. She settled to the bottom some distance from her target, *USS Housatonic*, but it may never be known if she flooded and sank as a result of the wash from the explosion that shattered *Housatonic*, or whether she was scuttled by her own poor seakeeping ability – a factor that killed two earlier crews and earned her the sobriquet 'peripatetic coffin.'

[14] Gunton, *Submarines at War*, 19.

the surface it was the most vulnerable to detection and attack, particularly in areas where aircraft might sortie over shipping routes to reconnoiter and vector surface combatants to their locale.[15]

With submarines in the inventories of most prospective belligerents as the war clouds gathered before World War I, military theorists were well-employed attempting to divine their impact on naval operations. From a defensive perspective, the submarine might prove a capable response to blockading fleets, and from an offensive perspective might provide an equalizer if it could neutralize some enemy warships. The naval construction "race" that preceded World War I was won by Britain in terms of the conventional concept of sea power: battleships. Admiral von Tirpitz, the architect of the German Navy, was also a staunch advocate of the battleship as the archetype of naval strength; but by the beginning of the war Germany's capital fleet was not ready to face the stronger Royal Navy, and the Kaiser was not prepared for the disgrace of a defeat of his prized ships. Germany therefore entered World War I with an alternative naval strategy that employed her plentiful if untested *unterseeboots*, or u-boats in the anglicized term for the German nomenclature.[16] Almost immediately, the German *U-9* answered the question about the submarine's potential versus surface combatants. Armed with only six torpedoes, in the space of about one hour in late September 1914 this small nearly defenseless craft with only 26 crew torpedoed a three vessel patrol of British armored cruisers. *Aboukir*, *Hogue*, and *Cressy* were sunk with a loss of over 1400 officers and men. *U-9*'s Kapitan Lieutnant Weddigen thought to spare *Cressy* to rescue the survivors of his first two victims, until his first officer admonished him that Germany faced four other navies in the war.[17] It was a horrific foreshadowing of the incivility of naval war in the modern age, one that respected not the chivalry of warfare that had first (perhaps accurately) assessed the submarine as an "infernal machine" of war, but victory no matter the toll.

The stunned British incorrectly estimated that five submarines participated in the attack on the three cruisers, and would scarcely believe it had been but one. The image of the merciless wolf-pack was

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[15] Brayton Harris, *The Navy Times Book of Submarines: A Political, Social, and Military History* (New York: Berkley Books, 1997), 232-241.
[16] Gary Weir, *Building the Kaiser's Navy: the Imperial Naval Office and German Industry in the von Tirpitz Era, 1890-1919* (Annapolis: United States Naval Institute Press, 1992), 127-128, 144-145.
[17] Thomas Parrish, *The Submarine: A History* (New York: Viking Penguin, 2004), 65.

invoked and entered the lexicon of naval warfare, although the vessels that were slaughtered could hardly have been considered defenseless innocents – even if in effect they were incapable of defending themselves against such a stealthy foe.[18] To a nation that measured her strength in seapower, it was a tremendous blow. More British seamen had perished in these three ships than the number of persons that died in *Titanic*, the leading maritime disaster of the era; three times as many were killed than were lost by the Royal Navy at Trafalgar, the great victory under Nelson.[19] It should not have caught the Royal Navy so completely off-guard: a few weeks earlier a sister u-boat had sunk a smaller British warship - an event that did not achieve near the same notoriety, but that was significant nonetheless as it was the first warship taken by an undersea vessel since the attack by *Hunley* on *Housatonic* over fifty years earlier.[20] With the early tally at four to zero in submarine-warship encounters, respect for the submarine should have immediately skyrocketed, but surely the tenets of naval warfare could not have been rewritten so suddenly. Soon the submarine must bare its Achilles Heel and be relegated to its proper station in the naval hierarchy.

Britain – and most interested naval observers - had expected the naval battle to be with Germany's High Seas Fleet. The three ship picket of *Aboukir*, *Hogue* and *Cressy* had been described as the "live-bait squadron" by others in the Royal Navy; they were stationed to warn of the approach of German warships, but were fully expected to be dispatched if they encountered them. When instead the bait was taken by a "shark of steel", it stunned the Royal Navy and the British people who had become accustomed to naval supremacy. Britain had been unprepared for the stealth with which Germany attacked…or the effectiveness of the submarine against capital ships.[21] Even after this encounter, expectations persisted that the decisive naval battle that would define the naval war would be fought between the largest and most powerful warships. The only such confrontation that did occur was the relatively inconclusive fight that eventually took place at Jutland in 1916. After this tactical loss but strategic victory for the Royal Navy, which lost fourteen warships to Germany's eleven, "when the German High Seas Fleet retired [to home ports], it became the German stay-at-home fleet" and the story of the naval war become largely one of the

[18] Gunton, *Submarines at War*, 25-27; Parrish, *The Submarine: A History*, 60-63.
[19] Parrish, *The Submarine: A History*, 62-64.
[20] Gunton, *Submarines at War*, 25-26.
[21] Parrish, *The Submarine: A History*, 58

German submarine offensive, and British and Allied efforts to stem its effect.[22] With the opening naval salvos of World War I, the submarine had proven itself an adversary to be respected, but even to this point it had not demonstrated the full extent of the threat it posed in naval warfare.

When the War to End All Wars began in 1914, international norms with regards to the propriety of targeting enemy merchant vessels and for confiscating contraband cargoes were in a state of flux. European Powers had attempted decades earlier through the Declaration of Paris to determine a framework for international maritime law with respect to the carrying trade of belligerent and neutral nations. Russia, France, Great Britain, Prussia, Austria, Sardinia, and Turkey signed this pact in 1857. Privateering - the practice by which States contracted independent raiders to capture enemy vessels or contraband cargoes under their aegis via instruments known as *letters of marque and reprisal* - was abolished; neutral flagged carriers were allowed to transport enemy goods with the exception of contraband (generally meant to be war materiel, but with room for interpretation); neutral goods were exempted from seizure under any flag; and significantly blockades were considered binding only so long as they were *effective*.[23] The United States participated in negotiations, but declined to sign the agreement because of the ban on privateering, a practice it had used to great effect against Britain earlier in its history. It was an asymmetric tactic that could be used by a nation with inferior naval strength, especially against an enemy with significant maritime trade. Ironically, the Confederate States Navy pursued a *guerre de course* strategy to great effect against Union merchant shipping in the American Civil War, in effect driving the American carrying trade from the world's oceans. It was a policy the Union condemned as piracy despite its ostensible support for the similar recourse of privateering.[24] The American conflict was the first significant test of this area of international law after the Declaration of Paris, but did not prove conclusive on some important fronts.

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[22] David D. Lewis, *The Fight for the Sea: The Past, Present and Future of Submarine Warfare in the Atlantic* (Cleveland: The World Publishing Company, 1961), 81.
[23] Marion C. Siney, *The Allied Blockade of Germany 1914-1916* (Ann Arbor: The University of Michigan Press, 1957), 2-4.
[24] The Confederate States did not consider its vessels privateers, but rather claimed them to be commissioned naval vessels. For its part the Union considered the Confederacy incapable of commissioning naval vessels let alone issuing *letters of marque and reprisal* to vessels that would empower them to legally privateer for the South. The situation became rather delicate for European observers with economic and diplomatic interests north and south of the Mason-Dixon Line that divided Union from Confederacy; to maintain the greatest degree of freedom, countries such as England and France ostensibly declared strict neutrality with respect to belligerents on both sides.

Ambiguities with regards to international norms of neutrality (the proper duties and responsibilities of neutrals; the rights of neutrals with respect to belligerents; etc.) and over which shipped goods constituted contraband cargoes persisted, as the practices observed by both belligerents and neutrals throughout the war did little to bolster any consistent customary procedure.

Critics of the 1857 agreement that had ostensibly been observed by its signatories during the "Late Unpleasantness in America" felt that the terms of the Paris Declaration too strictly limited the right to capture, and that the definition of what constituted a blockade was too open to interpretation. These issues were revisited at the Second Hague Peace Conference in 1907, and again at the London Conference the following year. The Declaration of London that resulted provided for stricter definitions of what might inherently be considered contraband, and what might always be considered on a "free list" for trade and not subject to confiscation, but the there were plenty of grey areas open to interpretation that made the interception of maritime trade in times of war a highly subjective enterprise. The United States joined the governments of Britain, Austria-Hungary, Germany, Italy, Japan, Russia, Spain and the Netherlands in the Declaration of London, but the treaty was not ratified by the signatories before the next round of hostilities commenced. Nevertheless, its general provisions were followed in British prize manuals issued at the outset of the war, and while they may not have been *established* norms they represented the framework understanding of what was considered the most appropriate way to prosecute the interception and blockade of merchant shipping.[25]

If the fine legal points of trade interdiction remained to be argued and prescribed under maritime law, there was a more general law of the sea that had long existed in an abstract sense and was very powerful among seafarers. Its "codification" at the Second Hague Peace Conference in 1907 was a formal statement of a tradition that existed ages before it was written down. "Every master is bound, so far as he can do so without serious danger to his vessel, her crew and passengers, to render assistance to everybody even

[25] Siney, *The Allied Blockade of Germany 1914-1916*, 5-13.

though an enemy, found at sea in danger of being lost."[26] All who ventured on the ocean faced the dangers of an environment that conspired with natural laws (gravity chief among them, as directly opposed to buoyancy) to drag them beneath the waves under the most benign of circumstances. Rendering assistance to those in peril on the sea was ingrained in the soul of mariners, even - as it came to be seen - to their detriment in time of war. One tactic of a Confederate raider in the American Civil War was to fire her prizes such that other vessels might sight the smoke or flames and alter course to assist their fellow seamen. Laying in wait, the raider pounced on ships that flew the Union flag or that carried Union cargoes (and lacked the foresight to at least "paper over" their own identity or that of their goods with alternative documentation). The Confederate Captain provided for captured crews and bonded vessels or cargo according to the norms of the Declaration of Paris; but he nonetheless affronted a tradition of the sea. As the fame of his vessel grew in northern newspapers, his actions made it less likely – at least while he still prowled the seas – for vessels to render assistance according to this long held tradition.[27] Fifty years later Kapitan Lieutenant Weddigen of *U-9* also acted out of tactical expediency - despite his reticence to violate this humanitarian norm - by dispatching the third British cruiser as he witnessed it rendering aid to the mortally wounded *Aboukir* and *Hogue.* During the attack, Weddigen deliberately torpedoed *Hogue* as she drew alongside to rescue sailors from *Aboukir*. *U-9* was still outnumbered and virtually without defense, but even if the submarine were not in danger *Hogue* was still an enemy warship, and the charitable view at that point was that a third vessel remained to recover survivors.

U-9's all-torpedo attack on the "live-bait squadron" was almost unique for early submarine warfare. If a submarine's torpedo load was already depleted or if its captain was husbanding inventory to avail of his weapon of optimal use in stealthy runs against armed foes, a submarine instead surfaced to attack using its deck-mounted guns. But consequently the submarine's vulnerability on the surface made it less likely to remain on scene to render assistance to any crews of sinking vessels. Naval warfare was witnessing an age of rapidly transforming technology and tactics that grew increasingly inured to the traditions of the sea that seafarers had respected for centuries. A sense of urgency and expediency was replacing the sense of

[26] "Convention for the Unification of Certain Rules of Law Relating to Assistance and Salvage at Sea," *Fletcher Multilaterals Project*, September 23, 1910 (accessed February 10, 2005); available from http://fletcher.tufts.edu/multilaterals.html.
[27] "The Pirate 'Alabama,' *Alias* '290.'" *Harper's Weekly*, November 1, 1862, 699.

chivalry and fraternity that had at least nominally existed even between belligerent navies. This subtle alteration of custom made subordinate to tactical "necessity" would ultimately contribute to Germany's naval downfall in World War I; for despite its legitimate strength as a naval warship, the submarine became something of a sinister shadowy undersea predator - especially after an effective propaganda campaign mobilized civilian outrage on both sides of the Atlantic over the loss of innocent life from submarine depredation. The German u-boat of the First World War methodically earned its reputation as a descendant of the original "infernal machines" and drew the rapt attention of navies to counter the threat that it posed.

At war against an island nation reliant upon exports for trade and imports for vital materials, it was readily apparent that Germany could benefit by attacking Britain's maritime logistic lifeline. Accordingly, when the Kaiser's submarines went to sea, it was not only to act as equalizers against a stronger British capital fleet that was expected to blockade German North Sea ports. Contradicting the conventional wisdom about the relative effect of a naval strategy that attacked an enemy's logistics versus one that sought decisive encounters with the enemy's fleet, the u-boats' subsequent success against Allied merchant traffic very nearly turned the war in Germany's favor. But this tactic of undersea warfare versus merchant shipping was something of a blunt sword that showed its steel to others beside Britain and her declared wartime allies. Conducting *guerre de course* from submarines required u-boat commanders to make targeting decisions at sea that went beyond the normal operational considerations related to successfully putting ordnance on target - decisions that had moral and political ramifications. Under the rules of search and seizure, submarines were required to surface and identify civilian and merchant vessels in order to protect neutrals from indiscriminate attack. In addition, it was expected that crews and passengers of lawful captures would be allowed to safely debark before the vessel in question was dispatched to the bottom if the situation mandated such action: "Before destruction, it is also a rule of international law that all persons on board must be removed and placed in safety and that all relevant ship's papers must also be removed and preserved."[28] But in the midst of battle where decisions and hesitations may mean life or death, the cool detached judgment of the law is often warped some by proximity to the flames of conflict.

[28] C. John Colombos, *The International Law of the Sea*, 3rd Revised ed. (London: Longmans, Green and Co Ltd, 1954), 644.

Britain did not idly absorb the punishing assault by Germany's submarine fleet against its surface vessels. As submarines began to take a heavy toll on British shipping – in the few months of war in 1914 they accounted for more than a quarter million gross tons sunk, and the following year more than quadrupled that number against British and Allied vessels – merchant vessels were often fitted out with deck guns. Furthermore, Britain made it a standing policy that no Allied submarine or aircraft would approach a merchant at sea, so that any such action witnessed by a merchant might be presumed hostile and defensive action taken without fear of what today is termed "blue on blue" fratricide. And the British began deploying dummy merchant vessels known as "Q" ships or "Special Service Ships" that were manned by Royal Navy crews and that mounted guns hidden by fake elements in the superstructure. These wolves in sheeps' clothing acted as decoys to lure submarines to an unexpected reception.[29]

Aggressive tactics such as these blurred the lines of what might properly be considered a merchant versus a combatant vessel, and took advantage of the grey areas that remained in international law since the Paris Declaration established rough guidelines decades earlier (the declaration of London was not in force as it was not ratified). But England's actions were not initiated unilaterally, preemptively bending international norms to her favor in countering Germany's *guerre de course* strategy. Germany blatantly had declared the waters around Great Britain a war zone in February 1915, decreeing that "every enemy merchant ship found within…[the waters around the British Isles]…will be destroyed without it always being possible to avoid danger to the crews and passengers."[30] Neutrals were not safe from submarine attack within this zone either, because of the reported "misuse of neutral flags by the British."[31] Apparently, because of the vulnerability to counterattack of the undersea weapon that Germany chose to employ to strangle British supply lines – and the tactical expediencies that resulted - it was acceptable to become selective among norms of maritime law. The dark humor of military punditry summarizes this black-and-white view of undersea warfare in an axiom endemic to the submarine service; it advises mariners that there are only two types of vessels: submarines…and targets.

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[29] Gunton, *Submarines at War*, 32; Hutchinson, *Submarines: War Beneath the Waves*, 68; Lewis, *The Fight for the Sea*, 36-50. Fourteen u-boats were sunk by "Q" ships and some 60 additional ones damaged by the end of the war.
[30] Quoted in Hutchinson, *Submarines: War Beneath the Waves*, 68.
[31] Robert D. Ballard and Spencer Dunmore, *Exploring the Lusitania: Probing the Mysteries of the Sinking that Changed History* (Toronto: Madison Press, 1995), 124.

By early May 1915 Germany crossed a line with its aggressive policy of submarine warfare. In addition to British warships and merchants, the Norwegian vessel *Belridge*, the Dutch *Medea*, and the American *Gulflight* – all neutrals – had been attacked. Only the Dutch vessel had been boarded; the other two were torpedoed without warning.[32] But the fateful shot that turned the tide against Germany's wholesale campaign of undersea warfare came from the tubes of the submarine*U-20*. Within sight of Queenstown, Ireland on May 7th, Kapitan Leutnant Walther Schweiger maneuvered his u-boat to arrange a bow-on firing position against a target he had not positively identified, but knew to be British as no other four-stack vessels of her size belonged to neutral parties. Schweiger logged a "clean bow-shot from 700 metres" that struck the vessel abaft the bridge on the starboard side with a great explosion.[33] *U-20*'s single torpedo sank a 30,000 ton steamship with the loss of almost 1,200 lives. The ship was a Cunard liner enroute from New York, and a large number of those lost – including almost 200 Americans – were women and children. Although this one act cannot alone be credited with drawing the United States into World War I, the effect it had on the political will of the isolationist nation should not be underestimated.

Propagandists on both sides waged a battle of public opinion over the sinking of the liner. The German satirical medalist Karl Goetz struck a medal indicating that the vessel carried contraband, and that the greed of the Cunard Lines led to the tragedy after a warning published by the German Embassy in the United States went unheeded and the vessel sailed from New York laden with passengers for England. For its part, British Intelligence seized upon the medal as further example of the barbarity of the Hun that exalted the feat which led to the death of innocents. To capitalize upon the event, intelligence officers had copies of Goetz's medal mass produced and sold them in presentation boxes to the British public for a shilling to raise money for war charities…and in no small measure to arouse the public's indignation at this outrage. Similar propaganda copies were later produced in the United States to the same effect.[34] Fueling the

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[32] Hutchinson, *Submarines: War Beneath the Waves*, 68.
[33] David Ramsay, *Lusitania: Saga and Myth* (New York: W. W. Norton & Company, 2002), 81.
[34] Ibid., 195-196. The medal itself further inflamed public sentiment when Goetz mistakenly inscribed the date of sinking as May 5th instead of May 7th. To the propagandists who sought to use this against Germany it was further evidence that the 'Hun' had fully intended to commit this dastardly act, and had merely miscalculated by two days the arrival of the vessel from New York. Although Goetz reissued his medal with the correct date, the (further) damage was done.

firestorm of anger over the sinking, dramatic renderings flourished in newspapers and magazines of drowning mothers clutching babies to their breasts while the limp bodies of children floated among the flotsam of the wrecked liner. Try as it might to defend its action under the rules of engagement that it had broadcast prior to the event, Germany paid the price for this aggressive view of its rights as a belligerent waging a new form of warfare. This signal event would be recognized long after the particular details faded from memory, and ensconced the u-boat as an infernal machine of the "barbarous Hun" - despite the fact that other nations on both sides of the fight employed them. To the list of "Remember!" rallying cries that angered and inspired Americans and included the *Alamo* and the more recent *Maine*, another name was inscribed. Through his periscope Kapitan Leutnant Schwieger made out in gold letters near the bow the identity of the vessel he had hulled as it settled low in the water; it was a name forever coupled with tragedy and with the savagery of this "infernal" undersea warfare. Schweiger noted the smoke and flames from secondary explosions and the confusion that reigned on the decks of the doomed liner as he recorded her name in *U-20*'s combat log: *Lusitania*.[35]

Science and the Sword

The introduction of undersea warfare was a watershed event that forced rethinking of conventional maritime tactics and strategies. First implemented in earnest during the American Civil War, undersea warfare flummoxed conventional warships which found themselves almost defenseless against the unorthodox weapons. Built around two technologies, the underwater torpedo (mine) and the fledgling submarines allegorically dubbed *Davids* because of the enormity of the task they were designed to carry out, undersea warfare was at first a nearshore proposition. Neither one of these undersea technologies could tactically be employed on the high seas with any degree of effectiveness in then-current configurations, so while they represented novel approaches to warfare, they were something of a poor man's Navy – and then only good from a coastal / harbor defense standpoint. Traditional naval power remained embodied in the line-of-battle man 'o war and its technologically enhanced progeny that reached their apotheosis in the dreadnought battleships that defined the naval arms race prior to World War I. Until

[35] Ibid., 82.

another naval platform categorically demonstrated cracks in the edifice of this Mahanian understanding of naval warfare, battleships would remain the centerpiece of naval strategy and indeed would dread nought from competing naval technologies.

The foundations of this bedrock notion of naval superiority were first rocked when the highly asymmetric methods of undersea warfare literally blew holes in the theory of capital warship dominance in World War I. Mine warfare was demonstrated effectively in harbor defense, and for use in straits and chokepoints such as the Dardanelles between the Mediterranean and Black Seas; and the modernized submarine with independent-running torpedoes became a force to be reckoned with even on the high seas, where capital ships traditionally held sway. Quickly it was demonstrated that undersea weapons delivered via stealth could do as much or more damage to conventional warships that remained unprepared or unable to defend against such attacks as could traditional heavyweight combatants hammering away with naval gunfire. In addition, the theretofore denigrated strategy of *guerre de course* was proven much more viable from a platform that was difficult to spot, either by potential victims or by the warships steaming in company for their protection. The obedient faith in established notions of naval superiority died as suddenly as the seapower prophet Alfred Thayer Mahan, felled by sudden heart failure in December 1914 at the cusp of the saltwater litmus test that would deliver some of his theories their comeuppance.

The submarine had definite limitations and vulnerabilities, but these were effectively exploited only once the threat that it posed was legitimately assessed for what it represented, and new tactics were devised to defeat the methodology the submarine employed to greatest effect. Convoys were principal among these tactics. Even though it might seem that traveling in a group presented a target rich environment for a submarine predator, it also provided more lookouts among ships in company to spot the telltale wake that feathered behind a periscope. Warships traveling with convoys could be better employed to serve a greater number of vessels as or more ably than if a lower ratio of warships to merchants in company was utilized. If *guerre de course* represented a strategy of attrition, then in large convoys numbers were on the side of the surface ship. Even the best employed submarines were target limited, especially if they wished to remain stealthily engaged (and thus restricted to the use of their valuable and limited supply of torpedoes)

while warships in company with convoys sought them out. Anti-submarine weapons were improved. Instead of having to maneuver above a submarine target to drop a depth charge, a method was developed to catapult them from destroyers allowing a more rapid prosecution of a submarine diving to escape. As the range and endurance of aircraft improved, they were attached to convoys as long range reconnaissance. Although problematic to gain a visual contact of a submerged submarine from an aircraft, it was not impossible. Submarines surfaced to replenish air supplies and to run their diesel engines to charge the batteries they used to operate submerged. This was not something they would typically do in crowded sea lanes and it was possible that aircraft might spot them at such activities outside the visual range of ships in convoy. Ironically the other undersea weapon to alter the nature of naval warfare - the underwater mine, in updated versions from the "torpedoes" of the American Civil War - was effectively used *against* the submarine, accounting for some 38 u-boat kills.[36] These methods were successfully employed against submarines in World War I, but the submarine was a technology that evolved and improved as well. Once it overcame the operational limitations that made it vulnerable to these tactics by diving faster, deeper, and for longer stretches of time – not in time, however, for implementation during World War I - the submarine ultimately retained its inherent threat value because of one non-malleable factor: the opacity of the ocean. Beneath the waves a submarine was near impossible to find. And to overcome this obstacle to anti-submarine warfare an even greater "weapon" was required…science.

Sight from Sound

Light attenuates rapidly with depth in water. Divers note that in shallow water marine life appears in all of its vivid color, but at depth in ambient light colors become more muted and objects appear in darker blues and greens. This occurs because shorter blue and green wavelengths of the natural light spectrum achieve the greatest penetration in water. The attenuation of electromagnetic waves results from a combination of absorption and scattering at the molecular level, such that the penetration of light in water is limited irregardless of water clarity. No large leap in logic is required to surmise that light would be attenuated more quickly by suspended particulates (and although less intuitive, also to some slighter degree

[36] Hutchinson, *Submarines: War Beneath the Waves*, 69.

by temperature effects). Consequently, even in the clearest of conditions light can only reach a few hundred meters down into the water column.[37] Visual detection of submerged objects therefore – even ones as large as submarines - is restricted to such a short distance that from a naval surface platform the tactical usefulness of such observation is decidedly limited. In fact, the distance is so short that one is reminded of the old maxim that when "an enemy is in range…so are you."

Hence, the preliminary problem of anti-submarine warfare is one of detection range – the further the better, obviously, but with less than evident means of execution to naval practitioners of the World War I era and earlier. Unless a submarine operated on or near the surface where by fortuitous circumstance it was spotted by a vessel or aircraft; or *if* it traveled near enough to the surface or raised its periscope and left a wake (which incidentally also creates a detectable radar cross section - although *that* electromagnetic detection technology was not in place until decades later during World War II); or *if* magnetic detection gear was close enough to register a disturbance in the earth's ambient magnetic field caused by such a large metal object (note: remember the range maxim); or *if* a submarine's radio transmissions could be triangulated (once radio frequency direction finding equipment was perfected) it enjoyed the stealth provided by the opacity of the ocean environment. Once the submarine was recognized as a legitimate naval threat, the primary challenge of antisubmarine warfare became – and remains to this day – detection of the platform while submerged. What was needed was a method to penetrate the opaque depths of the oceans, which for all intents remain impervious to most manners of effective search in the context of naval warfare. This meant identifying a search method that could scan a broad enough area quickly and efficiently, and that could achieve detection *before* the "enemy in range" maxim hazards the hunter himself. The most effective solution to overcome this murky obstacle and "see" into the depths, as it turns out, was as clear as a bell.

The polymath Leonardo da Vinci apparently formulated an idea for a submarine that would destroy the navies of his day, but he refused to elaborate on his musings for such a machine would be "too satanic…on

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[37] David A. Ross, *Introduction to Oceanography* (New York: Appleton-Century-Crofts, 1970), 151-153; H.U. Sverdrup, Martin W. Johnson, and Richard H. Fleming, *The Oceans: Their Physics, Chemistry, and General Biology* (Englewood Cliffs: Prentice-Hall, Inc., 1942), 80-89.

account of the evil nature of man."[38] Ironically, da Vinci also revealed an understanding for the principle that would prevent such a weapon from achieving immunity from prosecution in the depths of the ocean. In his journal he wrote, "If you cause your ship to stop, and place the head of a long tube in the water, and place the other extremity to your ear, you will hear ships at a great distance from you."[39] But if da Vinci had struck upon the key, the reverberations were not felt for hundreds of years until principles of underwater sound became better understood. The next demonstrated achievement in underwater acoustics took place in Lake Geneva, Switzerland in 1826. Colladon and Sturm experimented by striking an underwater bell with a hammer while simultaneously flashing a light to signal a listener ten miles away to record the time elapsed for the sound to travel underwater to a diaphragm stretched over the mouth of an ear trumpet. With this method Colladon and Sturm calculated the speed of sound in water to be 1453 meters per second, only slightly underestimating today's accepted value of 1500 meters per second. This apparently satisfied their scientific curiosity because they attempted no further refinement of their technique nor sought application for their discovery.[40] The exploitation of underwater sound remained untapped until near the end of the century.

The next purposeful inquiry into the properties of underwater sound took place concurrently in England and in the United States as a means to safely transmit signals as aids to navigation. Investigations into the difficulty of pinpointing the source of airborne fog signals led to the conclusion that they were untrustworthy as navigational warnings, and that an improved method was necessary to pass this vital information to vessels in times of low visibility. The transmission of sound underwater was then tested as an option and demonstrated some promise. Eventually this work led to the establishment of the Submarine Signal Company in Rhode Island in 1901. Here work was done to improve underwater microphone receivers and to resolve the directivity of underwater sound through signal processing based upon signal strength and arrival time at displaced underwater sensors. With confidence that sound might prove a

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[38] Quoted in Ernest Volkman, *Science Goes to War: The Search for the Ultimate Weapon, from Greek Fire to Star Wars* (New York: John Wiley & Sons, Inc., 2002), 66.
[39] Quoted in J.W. Horton, *Fundamentals of SONAR* (Annapolis: United States Naval Institute, 1965), 6.
[40] Temperature may account for deviation from accepted values in this empirical derivation of the speed of sound underwater, as sound travels faster in warmer water than it does in cold. Unless Colladon and Sturm conducted their experiments a number of times under varying temperature conditions they would not have noted this. H. J. W. Fay, *Submarine Signal Log* (Portsmouth: Raytheon Company Submarine Signal Division, 1963), 7-8; Gregory Haines, *Sound Underwater* (New York: Crane Russak, 1974), 13-14.

feasible method to relay warnings about navigational hazards, attention became focused upon the instruments that were to send and receive signals. Wave-operated bell buoys were developed in which wave action compressed a spring that automatically released to actuate the striker of the bell, providing a consistent blow to the casting and therefore a consistent underwater signal transmitted from the point of a hazard to navigation. On board ships, microphones were placed on either side of the vessel forward near the bow below the waterline. They were suspended in water isolation tanks to decouple them from interfering shipboard noise. Connected to an indicator box on the bridge, port and starboard microphones could be monitored alternately via a switch to aurally determine the direction of the signal. Submarine signaling in this fashion was well established by 1912, and ships were able to monitor bells along the east and west coasts of the United States and Canada, in the Great Lakes, along the coasts of England, in the North Sea, around the coastline perimeter of the Iberian peninsula from the Atlantic Ocean to Italy, and sporadically off the coasts of Brazil, Chile, and China.[41] Further refinement in the use of underwater sound came about when navies got involved…

After safety of navigation had been addressed via the introduction of bell buoys and shipboard microphones, the attention of scientists was then directed towards a system of underwater communication that would prove useful to navies. But a system for sending comprehensible signals underwater required a sound source that was better than the underwater bells developed for signal buoys. These bells emitted a powerful signal when struck, but the signal attenuated rapidly as the bell vibrated. Something with a cleaner, more discrete signal was necessary. This something was the Fessenden Oscillator, a reciprocating induction motor with a stroke only 1/1000th of an inch and that operated at 540 repetitions per second. Each repetition created a signal of equal amplitude, and generated sound waves powerful enough to dramatically increase the range at which Morse Code signals could be sent underwater intelligibly. What is more, the device could work as a receiver and translate the compression sound waves received at its face into electrical signals rather than requiring a microphone for this task. The first model had a two foot diameter oscillating diaphragm and weighed some 1200 pounds, thereby limiting its applications. But by 1914, an improved version of the Fessenden Oscillator "no bigger than a bushel basket" successfully

[41] Fay, *Submarine Signal Log*, 8-11.

transmitted signals at a rate of twenty words per minute for more than thirty miles underwater. With this improved device, "warning signals and coded messages could be sent 50 miles or more from shore to ship, ship to shore or ship to ship."[42] Although preliminary testing of this method proved the concept, installations with early models onboard U.S. Navy ships manifested design problems and were removed. But the technique was scientifically sound, and the Fessenden Oscillator opened the window on the world of underwater acoustic possibilities.

The emergence of the submarine threat in World War I provided a critical security impetus to the scientific study of underwater sound. The development of the Fessenden Oscillator and other advances made in underwater acoustics in the early 1900s were largely private undertakings of the Submarine Signal Company and like enterprises. But the emergent need to locate adversary "sharks of steel" led to the collaboration of private and government research in the United States. In October 1915, the U.S. Secretary of the Navy Josephus Daniels convened the Navy Consulting Board "for utilizing the natural inventive genius of Americans to meet the new conditions of warfare…we are confronted with a new and terrible engine of warfare in the submarine." Secretary Daniels invited Thomas Edison to serve as chairman of this group, asserting that "I feel sure that with the practical knowledge of the officers of the Navy, with a department composed of the keenest and most inventive minds that we can gather together, and with your own wonderful brain to aide us, the United States will be able, as in the past, to meet this new danger with new devices…"[43] The board's task was to sift through the many – sometimes fanciful – ideas that "inventive genius" imagined to locate and neutralize the submarine threat. Even Will Rogers offered his "advice," suggesting that the best method for finding submarines was to drain the Atlantic Ocean. Asked how that should be done, Rogers answered, "Well that is a detail. I am not a detail man."[44]

In February 1917, a subcommittee of the Navy Consulting Board was formed to address the potential for "Submarine Detection by Sound." Pre-War investigations had focused upon the detection of sound that emanated from fixed stations by receivers on vessels that were underway as a matter of navigational safety;

[42] Ibid., 12-14.
[43] Quoted in Harris, *The Navy Times Book of Submarines: A Political, Social, and Military History*, 199.
[44] Quoted in Ibid., 234.

was not the problem before them now almost the reverse? A partnership was formed between the Submarine Signal Company and two of the largest electrical companies in the United States, General Electric and Western Electric. Together these companies worked with the Department of the Navy at private facilities in Nahant, Massachusetts under the leadership of the University of Chicago's Nobel Laureate in Physics (and Reserve U.S. Army major) Robert Milliken, and at a new government facility set up by the Navy in New London, Connecticut to "study all naval problems bearing upon the detection and destruction of hostile submarines."[45] With respect to the study of underwater sound, science had been joined to security in a union that is now well on the way to its centennial anniversary.

By the time the Naval Consulting Board began integrating efforts in the United States to research the use of sound underwater to detect submarines World War I had already been raging for almost three years. With pressure mounting on Germany as the land war became locked in stalemate along the Western Front, the German High Command upped the ante in the naval war by declaring a policy of unrestricted submarine warfare in February 1917. America joined the war in April 1917, and German oceangoing u-boats began operating in earnest along the eastern seaboard of the United States. Ironically two months earlier when the United States severed relations with Germany, the news shared headlines with report of the sinking of an American vessel by a German submarine; the name of the ill-fated steamship was *Housatonic*.[46] In the three years that war was waged prior to U.S. entry, almost 50,000 tons of American "neutral" shipping had been sunk. In the remaining months of 1917, three times as much American tonnage – 148,424 gross registered tons – was sent to the bottom.[47] If the Naval Consulting Board needed any encouragement, it now had it…in spades. Far from idle, the government-industry consortium produced some novel acoustic devices; their introduction in the late stages of World War I impacted antisubmarine warfare, but so near the end of the conflict were not the decisive factor in the campaign. They were

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[45] Fay, *Submarine Signal Log*, 21; Paul G. Gaffney, II and John Petrik, "A Way of Life Enriched and Secured: The Nation's Debt to Oceanography," in *Oceanography: The Making of a Science* (Washington, DC: The H. John Heinz Center for Science, Economics and the Environment, 2000), 35.

[46] "Relations With Germany Are Broken Off; American Ship Housatonic Sunk, Crew Safe; Militia Called Out; German Ships Seized," *New York Times*, February 3, 1917. Tempting fate, the United States subsequently named a merchant steamship that was converted into a minelayer *Housatonic*. This vessel survived the war and was returned to its civilian owners with no additional hull breaches from her time in service.

[47] Hutchinson, *Submarines: War Beneath the Waves*, 68.

however significant early steps in developing effective acoustic detection devices that would make things considerably more difficult for submarines in future conflicts.

Continuing the investigatory track that showed the most promise, scientists improved the Fessenden Oscillator via the addition of a pliotron – an early vacuum tube – that amplified the weak electric signals the oscillator generated when it received sound impulses underwater. This enabled an operator with a telephone headset "for the first time to *hear* movements of ships at distances of many miles."[48] The sounds that were picked up came from a ship's propellers and its auxiliary machinery; in due course it became possible to categorize the type of ship by characteristic noises, and even to identify individual ships after multiple exposures to their idiosyncratic signals.[49] Eventually it was determined that even a submarine lying idle on the sea bottom emitted noises that could be picked up by this sensitive listening device. Based upon these experiments and working to develop an operational device that might make a difference in the war, the Submarine Signal Company succeeded in devising a microphone that was more sensitive in receiving signals than the Fessenden Oscillator, even in its improved version with the added pliotron. But many obstacles still needed to be overcome before this new "hydrophone" was successfully integrated into the fleet as an operational tool for antisubmarine warfare.

A sensitive listening device must be able to discern signals of interest from surrounding noise clutter to be operationally useful. Once detected, sound signals must then be localized, i.e. the azimuth and range of the sound source from the receiver needs to be determined. These problems were addressed incrementally. First, to decouple the hydrophone from own ship noises, it was hung from a float that was tethered by a cable some 200 feet from the ship, while all shipboard machinery was shut down. This "Drifter Set" was able to *detect* submarines at distance, but not *locate* them. To address the directivity half of this problem, the sound detection consortium looked to the principle that makes it possible for a person to identify directions from which sounds emanate. This "binaural sense of direction" is based upon slight differences in arrival time at each ear depending on the direction a person is facing in relation to the sound source. From sources directly in front or to the rear, sound arrives simultaneously at each ear, while if the source is

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[48] Fay, *Submarine Signal Log*, 22.
[49] Ibid; Gunton, *Submarines at War*, 18.

to either side there is a phase difference between the signals received by each ear, a difference which translates to direction when the brain processes the information. On this principle, two hydrophone receivers were placed at either end of a horizontal bar affixed to a vertical rod in the shape of a "T." Because the best signal processor was still a human, an operator wore a headset that piped in the signals from port and starboard hydrophones to the left and right ears respectively. Since the device needed to replicate the geometry that describes the arrangement of the receivers that humans use – ears – in relation to incident sound waves, the hydrophones were spaced at a greater distance apart than human ears to compensate for the greater speed of sound in water. The listener received the sound from either hydrophone receiver through a tube to the corresponding ear, and by turning the "T" as one would turn their head, the operator could adjust the angle of incidence of underwater sound at the hydrophones until it was in phase in each ear at which point the bar was perpendicular to the direction of sound travel.[50]

When this experimental apparatus was made operational, a third hydrophone receiver was added to determine directionality ahead or astern as the first two merely determined that sound was coming from one of these two directions when signals were in phase at each receiver. This "K-Tube" Set reached the fleet for use in World War I, but still suffered from the requirement that a listening ship must go dead in the water and shut off all machinery for the device to passively monitor for underwater signals.[51] Various means were pursued to overcome this deficiency including the development of a towed device that could operate while a vessel was in motion, as well as a distinct shipboard mounted multiple receiver model that was basically the forerunner of a phased array – a configuration where time delays (which translate to phase shifts) at consecutive receiving elements on the array determine direction. However by the time these advancements were implemented, World War I was winding down. At this late stage of the conflict, the sheer number of American destroyers that joined the fray brought as much (realistically more) to the anti-submarine fight against a weary u-boat fleet as had American science, but a critical new element of military power had been forged. After World War I, attention returned to improving the safety of navigation, and plowshares were forged from the sword of underwater acoustics. But use even in pacific pursuits would slowly but surely hone its edge for future conflicts.

[50] Fay, *Submarine Signal Log*, 23-26.
[51] Ibid., 26.

The end of World War I relieved the pressure that emphasized submarine detection as the prime focus of underwater acoustic research, and allowed another technique to be explored with greater attention: echo sounding. It had long been realized that an echo from an underwater explosion might determine water depth based upon the time of travel of the sound wave to the bottom and its subsequent return to the surface. This was theoretically simple, but operationally encountered problems – specifically in shallower water where the speed of sound is fast enough that signal return could easily be masked if the length of round-trip travel time was shorter than the length of the signal itself. A variety of signal processing techniques were experimented with, but a solution ultimately required the development of equipment that could generate extremely short pulses, measure the time for the signal to return and convert that measurement automatically into a depth equivalent. When these requirements were met, the device that was built became known as a fathometer, and the first commercial installation and trial in 1924 achieved a line of soundings from 5 to 1150 fathoms while the ship remained at speed.[52]

The introduction of the fathometer was a boon to navigators in that it provided an indication of where they might be located on a chart that displayed depth contours if all other (visual or aural) navigational references were unavailable. The clear indication of a shoaling sea bottom that such a device would signal to officers on the bridge at night and in times of low visibility was also invaluable in avoiding the greatest hazard to navigation – land. With an almost effortless means to plumb the depth of the water beneath the keel, the potential for improving the sporadically sounded charts that vessels employed for lack of better offerings was limitless. But this development also heralded a new technique that could be used against submerged submarines. For echo-ranging was not merely a vertical phenomenon; with the listening hydrophone aimed horizontally, returns could be received from submerged objects laterally displaced from the vessel. The first practical experiment of this technique had already taken place back in 1914.

Inspired by the *Titanic* disaster two years earlier, with an early version of his oscillator Professor Reginald Fessenden of the Submarine Signal Company demonstrated the ability to detect the presence of

[52] Ibid., 27-29.

icebergs more than two miles from the test vessel.[53] But earlier when the Fessenden device had indicated the potential for underwater communications in 1913, production models demonstrated practical shortfalls when the attempt was originally made to mount them aboard Navy ships. Consequently during World War I, the greatest research effort was placed in developing passive listening devices for warships to use in hunting submarines rather than attempting the more difficult challenge of devising active acoustic sources to seek out underwater contacts by transmitting sound pulses and monitoring for echoes. But not long after World War I, advanced hydrophone designs developed over the intervening war years made this technique practicable. An active system was devised that used an oscillator as a sound source and a sensitive hydrophone receiver to listen for returns. It was this design that was utilized in the fathometer, and that could be reconfigured for horizontal rather than vertical use to search for objects neutrally buoyant in the water column. The nearly undetectable submarine was about to be made "visible" in the otherwise opaque depths of the oceans.

By the early 1930s, "QC" echo-ranging devices were installed onboard U.S. Navy destroyers which were capable of determining depth beneath the keel while the ship was underway, as well as the direction and distance to submerged objects in the water column by actively "pinging" with sound and waiting for return signals. A more modern hydrophone design was now used as sound source and receiver, and separate hydrophones were used for vertical depth sounding and for horizontal ranging to underwater targets as well as telegraphic communications to ships with similar systems. Operated in a passive mode - not radiating sound to induce a reflected echo, but rather only utilizing the hydrophone as a receiver - this equipment was able to detect moving vessels whether surfaced or submerged by discriminating the higher frequency propeller and machinery noises they made. Directionality was enhanced for active systems when hydrophones were operated in a way that made the sound they emitted more of a "beam" that could be trained azimuthally by turning the hydrophone. Many of these enhancements were kept secret from scientists not working at the Navy labs, for with a resurgent Germany and rapidly arming Japan war was seen on the not too distant horizon.[54]

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[53] R.F. Blake, *Submarine Signaling - The Protection of Shipping by a Wall of Sound and Other Uses of the Submarine Telegraph Oscillator* (Washington: Smithsonian Institution, 1916), 203-213.
[54] Fay, *Submarine Signal Log*, 30-34.

After the success Germany realized with submarine warfare in the First World War, and the failure of the post World War I naval powers to limit submarine construction at the Washington Naval Conference in 1921, future naval war was likely to involve combat with newly designed submarines boasting the latest in technology and weaponry.[55] Accordingly every advantage that this new sonic direction and ranging system offered was husbanded for that time of need. This technology became known as SONAR, an acronym for Sound Navigation and Ranging - a nomenclature that describes the inherent duality of a system useful for both military and civilian applications.[56] The U.S. Navy practiced with its new equipment, training its operators and refining techniques to exploit the information quickly and effectively into anti-submarine attack strategies. But at times during this period of break-in testing and training, the equipment inexplicably failed to find submarines where surface vessels knew them to be during an exercise, and at other times reported them where the surface ships knew they were not. This was not a confidence builder and it was not a problem that the acoustic engineers, who had constructed the devices and determined them to be functioning as designed, were able to fathom. What the Navy encountered was a different dilemma, one that required the expertise of a new group of scientists - ones that understood that linearity was not the first principle to be relied upon in the variable ocean environment. The men called upon to address this perplexing problem were members of a nascent community of scientists gradually recognized as distinct from the physicists, chemists, biologists and geologists from which they evolved. Unavoidably required to transcend the academic boundaries in which they were schooled when it came to conducting investigations in the ocean environment, these interdisciplinary scientists became known by a new title: oceanographers.

Clarity Through Smoked Glass

Near Guantanamo Bay, Cuba in the summer of 1937, the officers of the United States Navy destroyer *Semmes* noticed that their sonar equipment performance degraded in the afternoon, sometimes failing to

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[55] Lewis, *The Fight for the Sea*, 86.
[56] Through repeated usage, the abbreviated title for Sound Navigation And Ranging devices has entered the lexicon as a word and is generally no longer capitalized as an acronym.

return echoes from submarine targets they knew to be present during training exercises.[57] The sonar sets otherwise performed as expected, so the question arose as to whether this phenomenon was a function of the ocean environment rather than the sonar gear or operator error. One of the lieutenants onboard thought that the problem might be related to plankton "effervescence" – outgassing during photosynthesis which might result in bubble formation that could interfere with sound transmission - and appealed to the fledgling Woods Hole Oceanographic Institution for help. Although Woods Hole director Henry Bigelow did not wish to involve the institution in "deep water plumbing" – applied rather than basic research – the Institution responded by dispatching oceanographer Columbus O'Donnell Iselin who sailed (literally) down to Cuba to investigate in the institution's research vessel, the steel-hulled ketch *Atlantis*.[58] What Iselin eventually determined was one of the first indications that undersea warfare would remain irrevocably connected to oceanographic science - even beyond the research and development phase of anti-submarine warfare acoustic technology - in the operational arena of naval warfare. For the phenomenon that *Semmes* encountered was neither a function of electronics or instrument design, nor a matter of training or operator error. It was a matter of the geophysical properties of the water column – and those conditions differed throughout the world oceans both temporally and spatially to varying degrees in any given location.

No matter where in the oceans a submarine threat existed, prevailing conditions *would* uniquely influence the surface Navy's ability to detect and localize submarine contacts, and stronger gradients of parametric change in either dimension of time or space would correspondingly complicate the anti-submarine warfare problem. From the opposing viewpoint, submarine commanders with accurate knowledge of these water properties might use them to tactical advantage to conceal their presence. The sonar technology that had been developed upon the earliest understood principles of underwater acoustics had demonstrated that submarines could be detected by using sound, but the ranges at which this was

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[57] The ships *Semmes* was named for Raphael Semmes, an officer of the United States Navy who resigned his commission and 'went south' during the Civil War. It is ironic that this vessel would be the one to encounter what became known as the "afternoon effect," a phenomenon that drew oceanography and naval warfare closer together. For Semmes unwittingly plays a larger role in this story, as he was the commanding officer of the Confederate raider mentioned earlier that fired its captures to lure other ships to his trap; what is more - as will become apparent later in this dissertation – through his exploitation of charts and sailing directions derived from the work of an early naval oceanographer, Semmes became perhaps the first naval officer to utilize scientifically gathered and organized geophysical data for martial purposes.

[58] Susan Schlee, *The Edge of an Unfamiliar World: A History of Oceanography* (New York: E. P. Dutton & Company, Inc., 1973), 286-287.

accomplished were relatively short and were initially based upon a linear time-distance relationship of direct path transmission of sound underwater. But the physics that describe the ocean are far from linear at anything greater than short distances. This was the intrinsic reality that *Semmes* had "inexplicably" encountered. Undersea warfare from that point on became something more than a matter of naval strategy, tactics and theory; or an engineering problem of naval architecture and armaments; or even a matter of the science of underwater acoustics that had brought it thus far. It became dependent on a broader scientific field still in its infancy, but one that was forced to mature in a remarkably short time to address a submarine threat that was orders of magnitude larger than the one posed in World War I.

The solution to the problem encountered by *Semmes* was found by taking the ocean's temperature. This was not a singular measurement such as one might obtain to determine the body temperature of a sick patient. It involved recording as nearly a continuous measurement as possible as temperature changed with water depth to demonstrate the temperature *profile* of the ocean. With the technology available to him, Iselin did this by sampling the temperature at various depths with mercury thermometers and interpolating between the samples to complete the profile. This process however was "accurate" only at each station where *Atlantis* anchored to conduct its measurements, rather than uniformly determining conditions over a broad area. Numerous stations needed to be sampled to form a grid of profiles from which a three dimensional image of ocean temperature emerged. After a few weeks of such measurements, Iselin determined that the thermal structure of the ocean changed dramatically enough after hours of solar heating each day to alter the propagation paths of the sound emitted by sonar sets between morning and afternoon operations.[59]

On a hot afternoon when winds were light, the upper ocean waters became stratified into successive layers that became progressively cooler with depth, rather than remaining one thick layer of homogenous temperature that would have been present if the waters had been thoroughly mixed. Wind would promote mechanical mixing via wave action, turbulence and friction-induced surface currents, so the stratification that formed and dissipated over time scales of a matter of hours was generally only achieved in relatively

[59] Susan Schlee, *On Almost Any Wind: The Saga of the Oceanographic Research Vessel "Atlantis"* (Ithaca: Cornell University Press, 1978), 108-109.

calm conditions. Overnight because of radiative cooling or convective mixing – or mechanical mixing if conditions promoted it - while heat was no longer added via insolation, the upper ocean became more homogeneous in temperature. Therefore, sonar operations encountered different ambient physical conditions between morning and afternoon exercises as the ocean became thermally stratified, and these differences accounted for changes in sound propagation that puzzled the officers and men of *USS Semmes*. That water temperature appeared to be the root of the problem appeared a reasonable conjecture; *how* it did this remained to be explained to the Navy by Iselin.

Although it is a pressure wave and not an electromagnetic wave such as light, sound refracts similar to the manner light does through a prism; but it does so as it moves through thermal layers in the water, bending away from regions where it travels faster towards regions where its speed is slightly slower. In the ocean sound speed varies with temperature, pressure, and salinity, but in the upper portion of the water column – where submarines primarily operate – temperature dominates this relationship. What results are various paths of travel for sound between a source and receiver, based upon the geometry between them as they are situated within the temperature gradient. In this sense a submarine is a virtual "source" of the reflected energy of a sonar pulse during an active sonar search, and the proper source of noises that a passively listening hydrophone registers. Years later in a biographical sketch about his contributions to the field, Iselin's identification of this effect on sound propagation as a function of the ocean's thermal structure was described as if there were an invisible hill behind which a submarine could hide as sound was refracted around its position.[60]

Although Iselin's hill analogy was a somewhat crude approximation for what was happening, it made clear to the average reader that a submarine could remain concealed in what would otherwise be plain sight if the waters of the ocean were a transparent rather than opaque medium. To purposefully accomplish this deception, a submarine commander needed to know the thermal structure of the ocean at his location in real time; likewise to defeat this tactic, a surface vessel would need to have this same information, albeit over a generally broader swath as its search function was more problematic. In a wartime environment it was

[60] "Ocean Frontier," *Time*, July 6, 1959, 44.

unlikely that either platform would endeavor – or realistically *could* endeavor - to conduct a survey such as the one that was painstakingly done by Iselin on *Atlantis*. However, with the relatively short detection ranges involved, even a single profile could prove the presence or absence of thermal conditions that might support such tactics. To avail of this knowledge then, some method was needed to quickly make such a determination in a tactical environment.

Not long after he worked with the crew of *Semmes* to resolve what he labeled the "afternoon effect", Iselin had the opportunity to collaborate with another scientist from Woods Hole who was also interested in the thermal structure of the ocean. To investigate temperature variation in the Gulf Stream, Athelstan Spilhaus and his mentor Carl Gustav Rossby had constructed an instrument that was able to make continuous profiles of the vertical temperature gradient. By means of a stylus actuated along the y-axis via pressure as the device descended, and along the x-axis by a bi-metal strip that measured temperature by the differential expansion and contraction of the two metals, a plot of temperature with depth was etched on a glass slide that had been smoked with skunk oil.[61] To further investigate the influence of the ocean's thermal structure on sound propagation underwater, Iselin and Spilhaus operationally tested the device in company with the *Semmes* and a submarine. Spilhaus' instrument - known as a *bathythermograph* or BT – was a success and the Navy soon ordered two models for further testing.[62]

A short time later, while working on a contract issued by the National Defense Research Committee, Maurice Ewing together with his students Lamar Worzel and Allyn Vine redesigned the BT so that it could be raised and lowered from a moving ship making it much more operationally effective. When Ewing was dispatched onboard *Atlantis* in October 1940 with his improved BT to make temperature surveys in order to construct "sound condition charts" for the Navy, Iselin warned him about the need for secrecy, "We would be in serious trouble should it become generally known how and why the bathythermograph observations are being made. It will be best simply to say that the purpose of the cruise is to secure data on the effect of the wind and weather on the sea surface. Needless to add, if you should be questioned by any naval officer

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[61] Gary Weir, *An Ocean in Common: American Naval Officers, Scientists, and the Ocean Environment* (College Station: Texas A&M University Press, 2001), 126.
[62] Ibid., 126-127.

of a foreign country you are not to disclose to him that our work is in any way associated with the U.S. Navy. In this connection you are to see to it that no reference to the Navy appears in the log, in letters…, or in the ship's papers."[63]

The dual significance of oceanographic information for its scientific value in explaining the natural world, and for its military value with respect to naval operations, is made evident with unintentional clarity in this warning from Iselin to Ewing. It is a relationship that would stymie oceanographic research in the future and complicate the politics of the ocean dramatically over the decades to follow. But in such tumultuous times not long before the United States entered World War II, there was not the luxury of worrying whether loyalties were divided between pure science and military application…there was an impending war to win. After successful testing of the dynamically operable BT, another model designed for submarines (called an SBT) was developed. When war came to America anon, the Woods Hole scientists began training naval officers in the use of these devices. Those from surface ships were taught the use of the BT, what it revealed about sound propagation in the oceans, and how that affected sonar performance when they searched for submarines; for their part, submariners learned how to employ the SBT and how to best use the thermal structure of the oceans to their own tactical advantage.

> *The ENG officer is happy to be able to forward this card because it means we were able to "walk away" from this one…following a successful attack on a heavy cruiser. As we hit 300 feet the countermeasures started which severely damaged this sub. We were able to stay under the sharp gradient at 240 FT. and gradually pull away from the scene of the attack licking our wounds. The 7 Jap escorts continued to harass us, but their efforts became less and less fruitful as we moved away under the layer. My sincere thanks to Allyn Vine of the Woods Hole Inst. for the time he spent explaining the value of BT observations to me. When we were finally able to come to periscope depth the escorts were still getting an echo back at the scene of the attack and dropping sporadic charges. We on the SS 363 have always believed in the BT but this attack made salesmen for BT out of us.*[64]

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[63] Schlee, *On Almost Any Wind*, 109.
[64] For some years these reports and the BT trace that accompanied them occupied a frame in the lobby entrance of the Naval Oceanographic Office in Bay St. Louis, Mississippi. While assigned there in the

USS Guitarro had attacked and received a "share" in the sinking of the Japanese heavy cruiser *Kumano* in November 1944...and lived to tell the tale. Earlier that autumn, this same submarine had utilized the BT in another very important operation to evade pursuit. "Sighted by three destroyers in bright moonlight. Went deep and tho [sic] they passed close overhead they never got on us. The trace down & up are noted with interest as we surfaced only 2 ½ hrs later [the BT trace was sent along with the patrol report and demonstrates a strong thermocline between 160 and 300 feet in depth]. The layer at 160 FT. was one of the best we've ever found & allowed us to escape at 80 turns undetected." It is interesting to note that on this patrol report it is annotated that surface waters were almost 90 degrees Fahrenheit, with light winds and calm seas – almost textbook conditions for Iselin's theory of thermal stratification (as verified by the BT trace) and an ideal scenario for *Guitarro* to implement the recommendations prescribed by the ocean scientists for this set of environmental conditions in order to maintain stealth. And on that long ago evening in the South Pacific, that is precisely what the submarine needed to do.

Guitarro had encountered ships of the Japanese Central Force enroute to the scene of what became known as the Battle of Leyte Gulf. The sub tracked the enemy vessels through Mindoro Strait in the Philippine Archipelago, and although unable to align and close for attack, *Guitarro* notified Admiral William Halsey's Third Fleet which subsequently engaged and defeated the Japanese. The Imperial Japanese Navy was effectively driven from the war in this encounter, a massive affair in which 244 ships fought the largest naval battle in history and the last major naval action of World War II. In its own small way, by enabling *Guitarro* to act clandestinely as the eyes and ears for the fleet, the BT - and the science of oceanography from which it was developed – demonstrated clearly its value to the Navy.[65]

early 1990s the author had a photograph made of the display because of the significance such a pithy yet descriptive statement made about his profession. During the writing of this dissertation it was learned that some time since the frame had disappeared and has not been found. It is noted with regret, but with the hope that such an important artifact of naval history is eventually restored to its proper place of view. In the interim the photograph continues to serve as inspiration, not in a small part as muse for this current work.

[65] United States Navy Naval Historical Center, *Dictionary of American Naval Fighting Ships*, August 30, 2004 (accessed February 17, 2005); available from http://www.history.navy.mil/danfs/g9/guitarro.htm.

Submarine warfare in World War II was every bit as intense if not more than when the undersea weapon was introduced in earnest to naval warfare a few decades earlier. With improved active sonar detection gear widely distributed among surface combatants, the submarine did not possess the cloak of invisibility that the waters previously had woven for it in their opaque depths. But as prewar ocean research had shown, there were times that the physical properties of the oceans might still shroud a submarine's presence. Although both Japan and Germany possessed oceanographic capability, it does not appear in post-war analysis that they utilized it to near the same extent as did the United States and Allied navies in the undersea war. The German Navy did famously utilize knowledge of undersea currents such as the one that streams out of the Mediterranean at depth to steal out of that body of water and into the Atlantic without detection by securing machinery to "quiet ship" and drifting along with the flow. But it does not appear that either the *kreigsmarine* or the Imperial Japanese Navy dynamically sampled the physical properties of the *in situ* environment as operations unfolded wherever they found themselves in the oceans in order to take them into account tactically.[66]

The difference in such practices may appear minute, but they have enormous implications. Previously collected knowledge of the physical properties of the ocean environment at individual locations is useful, but the environment changes continuously. The pertinence of historical observations and climatic summaries is limited in spatial and temporal applicability even in a well studied region, so while useful for advance planning, relying on such data for real time operations may not provide the tactical advantages expected. This is somewhat analogous to daily changes in the weather; it varies more so in some locations than others, but rarely does the weather remain precisely the same at all times in all seasons, especially on shorter time scales of weeks to days because it is subject to numerous small scale influences. This is true of the oceans as well, albeit conditions may persist over longer time periods as the waters do not *generally* change as rapidly as the atmosphere – with important caveated exceptions such as the "afternoon effect." The introduction and application of oceanographic principles to the tactics of undersea warfare represented a fundamental shift in capabilities: the wherewithal to sample the environment in real time in order to

[66] "Ocean Frontier."

tactically avail of its ever shifting physical gradients to fight underwater more effectively was a powerful "force multiplier" indeed.

The central utility of a "force multiplier" is that it leverages a military capability to make it more effective. In this sense, the advantages that ocean science provided military operations in World War II were not confined strictly to the realm of undersea warfare. For in addition to a better understanding of the oceans for the growing use of acoustics in submarine detection, naval forces of World War II required a plethora of environmental information about the maritime battlespace that quickly expanded the scope of investigations of the oceans for naval application. An understanding of currents and prevailing winds was necessary for the routing of ocean convoys and the rescue of shipwrecked crews and downed aviators. Silk survival maps were printed that showed the best available information – classified for the military advantage it offered – for lifeboat navigation and for estimation of drift to avoid enemy forces and to locate friendly ones. Fathometers deciphered and recorded the bathymetry of the ocean floor along numerous tracks of ships throughout the war; in addition to its relevance to safe navigation, knowledge of ocean bottom topography was essential for undersea warfare as it could shield both hunter and hunted.[67] Hydrographic surveys were necessary for all naval operations, but particularly for the close-in naval operations of amphibious forces and surface ship naval gunfire support to troops ashore. Also crucial to amphibious warfare was information on near shore currents and the ability to predict tides and surf conditions for assaults in which troops struggled to cross the surf zone with weapons and equipment under withering enemy fire. This was a bloody lesson learned by the U.S. Marines at Tarawa in 1943.

To address these critical aspects of amphibious assault operations, two Scripps Institution of Oceanography scientists, Harald Sverdrup and Walter Munk, developed surf forecasting techniques that predicted the height, length and speed of propagation of storm-generated waves and described how these would determine surf as they moved ashore; their methods were successfully used in the amphibious invasions in North Africa, Sicily, and in the D-Day landings in Normandy. Other methods of remotely

[67] Deborah Day, "Navy Support for Oceanography at Scripps Institution of Oceanography," 2000 (accessed May 16, 2001); available from http://scilib.ucsd.edu/sio/archives/siohistory/onr.html; John A. Knauss, "The Emergence of the National Science Foundation as a Supporter of Ocean Sciences in the United States," in *50 Years of Ocean Discovery* (Washington, DC: National Academy Press, 2000), 3.

inferring nearshore properties were developed from aerial photography. In Sicily and Normandy, German commanders apparently thought surf conditions too severe for successful assaults, but U.S. forecasters using the Sverdrup-Munk techniques thought differently and were proven correct.[68] Many civilian oceanographers went into uniform, and oceanographic institutions churned out information for the war effort under the influence of wartime funding. When the war ended in 1945, American efforts in oceanography were maintained by oceanographers that returned to their institutions out of uniform or took new positions in the United States Government.[69] The United States Navy established the Office of Naval Research (ONR) in 1946 to transition wartime scientific efforts to peacetime pursuits. It was never a transition the oceanographic community was allowed to fully make; naval requirements for research and development would remain high priority as the Cold War Soviet adversary soon replaced the Japanese and German adversaries of World War II.

Run Silent, Run Deep

Submarines played an important role for the navies that fought World War II, but the "Silent Service" did not receive the same notoriety as the exploits of surface combatants or the new surface ship platform that performed to such devastating effect in warfare against both land and sea-based targets: the aircraft carrier. For all appearances, the Pacific war was much more of a naval war than the one fought a hemisphere away; this may be disputed by participants in the brutal Atlantic campaigns, but nonetheless the sense when viewed from historical perspective. And over the wide expanse of the Pacific, the aircraft carrier became the means to transport firepower that was delivered by dive and torpedo bombers, and initiated the advent of naval battle between forces that were far beyond the range of naval guns. The most famous battles of the Pacific war involved submarines, but were dominated and won by airpower: Pearl Harbor, Coral Sea, Midway, Leyte Gulf. The carrier became the new strategic naval weapon, relegating the battleship that had dominated naval strategy to limited engagements with other surface vessels, and to naval gunfire support for amphibious operations. The submarine, lethal as it was against both warships and

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[68] Roger Revelle, "The Age of Innocence and War in Oceanography," *Oceans*, March 1969, 11.
[69] William J. Merrell and Glenn Boledovich, "People, Institutions, and Discovery," in *Oceanography: The Making of a Science* (Washington, DC: The H. John Heinz III Center for Science, Economics and the Environment, 2000).

merchant shipping, remained a tactical weapon – an important one that justified the research and innovation accomplished by the oceanography community to improve both offensive and defensive tactics – but not one that held the entire attention of naval strategists. But this would not remain the case in the years following World War II, years that saw former allies the United States and the Soviet Union square off in what would become a confrontation that spanned four decades: the Cold War. As this superpower standoff progressed, the submarine acquired entirely new significance for both sides; monumental effort went into improving submarine technology, and that of the weapons systems the submarine carried. As both the import and attention paid to submarines grew, the science that most supported the military tactics of undersea warfare grew right along with it.

Despite the advent of better sonars and the evolution of anti-submarine warfare tactics by the end of World War II, the submarine continued to pose a potent threat against surface ships - and its greatest asset was still its stealth. For even with the technologies developed to defeat submarines, finding them when submerged was a needle in a haystack proposition. In good conditions sonar detection ranges remained down in the scope of a few kilometers, and detecting submarines before they reached weapons-release range remained problematic for those that hunted them. Quiet running submarines might avoid detection below thermal layers while well within striking distance of their torpedoes. On the other hand, on the surface the submarine was quite vulnerable to detection by patrol aircraft and by surface search radar that had been introduced and used with effect in World War II. Safe in the bosom of the sea, then, why would the submarine even surface? The answer to this question identifies the diesel-powered submarine's Achilles Heel, for at some point periodically it had to surface to ventilate and to run its diesel engines in order to charge the batteries it then used to turn the shaft while submerged. While a submarine could conserve its batteries to extend its endurance beneath the waves, it was still limited by the dangerous buildup of carbon dioxide and carbon monoxide that could disable and ultimately kill its crew if fresh air was not replenished.

The tactical importance of remaining submerged to preserve stealth was recognized by the German Navy as witnessed through their development of the Schnorkel-mast in the 1930s, an innovation that allowed the submarine to remain at periscope depth yet still operate its diesel engines and draw in fresh air.

The technology was offered to the British prior to World War II, but they declined. After experiencing firsthand Germany's aggressive tactics while employing the Schnorkel, the Americans and British quickly adopted it by studying captured German submarines.[70] This proved critical not long after World War II ended, when the ensuing Cold War developed between the United States and her former ally the Soviet Union. If the submarine had proved its value in the World Wars while still ranking rather low in the hierarchy that measured naval power, in the Cold War that followed it quickly rose to prominence in naval warfare. Its ascent began almost immediately in the opening days of this confrontation, when the United States called upon the stealth the submarine offered to monitor Soviet fleet activity and, more importantly soon thereafter, to garner information about the testing of Soviet missiles.

The nuclear weapons monopoly enjoyed by the United States at the end of World War II was short lived. In the race for nuclear supremacy that followed, once both sides had nuclear and later thermonuclear weapons the issue of primary import was delivery. The United States and the Soviet Union "inherited" German missile technology and employed it to develop rockets to carry men and material payloads into space, as well as versions that could deliver warheads to the other's military infrastructure and cities. Range and accuracy were the keys. Greater accuracy implied not just the ability to hit a target, but the ability to destroy the adversary's nuclear weapons before they could be employed. Greater range made it possible to launch a strike from further away, encompassing a greater arc from which to threaten the opposition, a perimeter along which the enemy was required to spread his forces to try to prevent the attack. In the early days of the Cold War, the United States was able to station weapons in allied countries of Europe, within range of striking the Soviet Union with early missile technology in addition to aircraft deployed nuclear weapons. The Soviets did not have reciprocal bases from which it could hit (vital) U.S. territory, but wanted them desperately. The Cuban Missile Crisis of October 1962 illustrated how crucial an advantage this was to the Americans and to what lengths the Soviets were willing to go to level the playing field. Consequently, the Soviet Union placed enormous emphasis on extending the range of their

[70] John Moore, ed., *Jane's Pocket Book of Submarine Development* (New York: Collier Books, 1976), 5.

missile delivery systems. The United States in turn focused on determining the growing level of Soviet capability.[71]

The submarine provided the stealthiest platform to eavesdrop on the testing that often ended with missiles or warheads crashing into the seas in Soviet test zones. The early attempts the United States made to station submarines to intercept communications and missile test radio transmissions from the Soviet fleet were risky missions. The diesel boats that the Americans had used in WWII were required to surface to recharge batteries and ventilate. The U.S. embarked on a crash program to integrate the German Schnorkel-mast technology to provide for more stealthy approaches, while maintaining at the same time a full battery charge in case the submarine needed to submerge past periscope depth and evade. The first attempt the United States made to use this improved stealth ended in tragedy. *USS Cochino*, hastily converted into a listening post by adding antennas and a "black box" cryptographic capability, sank on its first deployment in July 1949 to collect radio intelligence near the Soviet Northern Fleet homeport of Murmansk on the Kola Peninsula.[72] Although *Cochino* was not sunk by Soviet action, Soviet surface and submarine forces were nevertheless on the lookout for intruding American presence.

The dangerous game of cat and mouse continued for the U.S. diesel boats as steadily advancing Soviet missile technology made intelligence ever more critical to the Americans. Even with the adapted snorkel technology, the limitation of the diesel boats became all too apparent. Dependent upon periodic visits to the surface to replenish air and charge their batteries, diesel boats were vulnerable to detection and "holddown" by Soviet surface forces. Aggressive searches and pursuits were used to force a submarine to either remain submerged for dangerously long periods, or to surface and suffer the ignominy of being revealed as an interloper…or worse – for the Soviets were determined to deny access to their missile test zones and other areas from which the submarines could glean intelligence. The near disastrous holddown of *Gudgeon* in 1957 and later of *Wahoo* in 1958 demonstrated this serious limitation. Soviet submarine technology was no better, but the United States did not force a Soviet boat to the surface after holddown

[71] William J. Broad, *The Universe Below* (New York: Simon and Schuster, 1997), 69-70; Sherry Sontag and Christopher Drew, *Blind Man's Bluff* (New York: Public Affairs, 1998), 6.
[72] Sontag and Drew, *Blind Man's Bluff*, 1-24.

until 1959, when *Grenadier* captured a case of Jack Daniels offered by the Atlantic Fleet Commander-in-Chief as prize for the first such successful action.[73]

Nuclear powered submarines (the first, *Nautilus*, was launched in 1955) were soon called upon to remedy the shortfall in diesel boat submerged endurance. Independent of the need to surface like the diesel boats, nuclear submarines were not vulnerable to holddown and could take greater risks to achieve greater rewards. The boats carried years' worth of fuel in their reactor cores, could produce their own fresh water and oxygen, and were ultimately limited only by the amount of food they could carry and the time underwater that their crews could endure.[74] The ability to remain on station for long periods of time to monitor Soviet testing won for submariners a critical mission in Cold War strategy as an intelligence platform, a role that submarines still fulfill even in light of the modern intelligence capabilities provided by satellites and other platforms. The intelligence role of the submarine in the Cold War was an important one, and nuclear power had greatly extended the submarine's capability, but the technology that ultimately determined the centrality of submarines to United States naval warfighting doctrine was the ability to launch missiles capable of delivering nuclear warheads to the Soviet Union. Suddenly, there existed a menace that could not be ignored or avoided. Regardless of how effective a Soviet attack on the United States' ground based nuclear forces, if an American missile boat remained the U.S. retained the ability to launch a second strike.

Based upon the German rocket technology that the United States inherited at the end of World War II, the relatively limited 300 to 400 nautical mile range nuclear-capable *Regulus* missile was developed and went to sea on surface ships and aircraft carriers in the early 1950s. It was subsequently adapted to the constraints of carriage onboard and deployment from submarines, and went to sea operationally in this capacity in 1959. While the submarine-launched *Regulus* represented a technological breakthrough and a weapon that could evade targeting in a first-strike attack scenario by an enemy, it required the submarine to

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[73] Ibid., 25-41. In the course of this current research, the author discovered that his uncle was an enlisted crewmember onboard *Grenadier* during this period. To his dismay, however, the author notes that this former submariner refuses to either confirm or deny the involvement of *Grenadier* in any such operation, or that the whiskey was any good.
[74] Ibid., 42.

surface to fire. But soon after the *Regulus* went to sea on submarines, the vertically launched *Polaris* missile was proven in 1960 and deployed a few years later. *Polaris* trebled the range of *Regulus* and could be fired while the submarine remained submerged; with this ability the United States Submarine Force became firmly established as the third leg of a nuclear triad that also included land based nuclear-tipped missiles and air deployable nuclear weapons. Nuclear powered propulsion enhanced and extended the threat of the missile boats. Introduced with *USS Halibut* in the *Regulus* days, the technology was the standard for the *Polaris* boats. Submerged on patrol, they were virtually invisible for the months they remained on deployment. The United States produced no additional diesel submarines and slowly retired the remaining diesels in the inventory over the next few decades.[75]

Witnessing the development of the American missile capability within its submarine force, the Soviet Union recognized the answer to its own weapons' range/proximity limitations in submarine launched ballistic missiles. During the Cuban crisis, with even just a few *Regulus* boats at sea, the United States held a second-strike deterrence ace up its sleeve. Although increasingly able to target American soil with land based ballistic missiles, the Soviets knew that the easiest way to keep the United States unsure and off balance was through its formidable submarine fleet, and it fought to stay in the race for undersea supremacy. The subsurface contest between the two superpowers wore on. Technology spurred greater range missiles, quieter submarines, more advanced detection gear, and a more harrowing undersea competition to gain the upper hand. As typical of other Soviet tactics, quantity weighed over quality. The United States maintained a technological edge in most areas of submarine development, but the Soviet Union developed a crushing superiority of numbers.[76] Without a doubt, the USSR was more prolific in the classes and numbers of submarines it sent to sea, and churned them out in volume to the very end of the Cold War. As American technology made Soviet boats easier to follow and their own less likely to find, the Soviets went to great lengths to neutralize this advantage through technological espionage. The Walker Spy Ring scandal, in which a former American naval officer compromised many submarine secrets, as well

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[75] Norman Polmar, *The Ships and Aircraft of the U.S. Fleet*, 12th ed. (Annapolis: Naval Institute Press, 1981); Sontag and Drew, *Blind Man's Bluff*, 42-5; Nick T. Spark, "*Regulus*: The First Nuclear Missile Submarines," (United States: NSDSS Productions, 2002).
[76] Polmar, *The Ships and Aircraft of the U.S. Fleet;* Norman Polmar, *Guide to the Soviet Navy*, 5th ed. (Annapolis: Naval Institute Press, 1991).

as an incident in which the Soviets acquired special milling technology from Toshiba to aid in the quieting of submarine propellers, are among the successful efforts the Soviets made to remain competitive.[77] As submarines became progressively quieter and could remain submerged much longer, it was a greater challenge to detect them.

Availing of the (by then) reasonably simplistic acoustics of thermal gradients first discovered through the investigation of the "afternoon effect" was no longer enough to provide the tactical advantages realized in World War II and the years immediately following the conflict. A great deal more information about the ocean environment was necessary to better resolve the subtleties of underwater acoustics to wring as much information from the sounds emitted by enemy submarines as could be wrought. The scope of oceanographic investigation expanded rapidly to meet these needs. The United States Navy pursued an integrated military-scientific strategy beneath the waves, one in which the physical properties of the ocean became the independent variable of an equation in which the dependent variable – the one upon which rested success or failure in undersea warfare – was the propagation of underwater sound. It was through these efforts, aside from the submarine design and missile technology races, that the Americans achieved successes deep in the oceans that proved even greater coups, and which the Soviets never successfully duplicated. While some parameters or tasks could be measured or accomplished remotely, for others there was no real substitute for being there…

Run Silent, Run, Very Deep

While it was the province of naval powers to develop weapons of undersea warfare, it was the experimental efforts of private individuals that first developed craft that could plumb the depths. Submarines were vehicles of the upper thousand meters of the water column at most. Below these depths, early submarines would no longer able to withstand the crushing pressures and implode. Submergence past test depth - the deepest allowable operating depth and at times an empirical as much as theoretical limit - was forbidden; past crush depth, a dive was unrecoverable. It was there though, to the furthest reach of the

[77] Polmar, *Guide to the Soviet Navy*, 91-4.

abyss, where scientists and adventurers sought to go to satisfy a curiosity about what they might encounter. It was a goal achieved after ages of incremental steps… The earliest recorded attempts to supply air at depth in order to explore were described by Aristotle in the fourth century before Christ. Later legends tell of Alexander the Great diving in a chamber of glass. Methods changed little through the centuries; in various forms a diving chamber or bell was used to recover items from the deep – more notable events were recorded in 16th and 17th century Sweden and England when cannon were recovered from sunken warships using this technique. Technology also evolved to allow man to dive independent of a diving bell. Before the close of the 17th century, a self-contained leather diving device was developed in Italy. In 1797, a diving helmet supplied with pumped air was introduced in Germany. The 19th century saw development quicken, with diving suits and a breathing apparatus that had an automatic demand valve and a diver-carried reservoir of air. The end of the century witnessed the advent of underwater photography.[78]

During the first decade of the 20th century, scientists realized a greater understanding of man's ability to function underwater through the empirical development of underwater decompression tables and an underwater decompression chamber. In the 1920s, Yves LePrieur invented a self-contained compressed air lung, and Charles Momsen's oxygen-rebreathing escape lung was adopted by the U.S. Navy. Diving in an armored suit, Jim Jarratt located the sunken *Lusitania* in 330 feet of water in 1935. A few years earlier, divers in similar suits had reached depths of over 400 feet to recover tons of gold from a wreck off the coast of France. American experimental divers achieved success using a helium-oxygen mix and soon thereafter implemented the technique during recovery operations when the submarine *Squalus* sank in coastal waters off New England in 1939. Although further experimentation was successful with other gas mixtures and diving equipment, perhaps the greatest liberating invention for diving debuted in 1943 when Jacques-Yves Cousteau and Emile Gagnan introduced their fully automatic Aqua-Lung.[79]

The developments chronicled above enabled man to dive well beyond his natural ability. Diving suits allowed descent to a few hundreds of feet before pressure prevented further travel; armored suits could

[78] Sylvia A. Earle and Al Giddings, *Exploring the Deep Frontier* (Washington: National Geographic Society, 1980), 286-288.
[79] Ibid.

double that depth, but to go further humans needed mechanical assistance. The bathysphere (bathy is Greek for deep) was a metal ball large enough to fit two men, designed by oceanographer William Beebe and built by engineer Otis Barton in 1929 under the aegis of the New York Zoological Society in 1929. Little more than a hollow steel ball with a thick glass view port, it was designed to withstand large evenly applied pressures so that Beebe might explore the ocean depths and view the creatures he wished to study in their natural habitat.[80] Submarines of the day could only cruise at about 400 feet before they could no longer withstand the pressure.[81] Beebe and Barton descended to 1426 feet in the bathysphere in 1930 - over three times the deepest operating depth of a conventional submarine and well beyond the greatest depth that could be reached by a diver in an armored suit. Barton calculated that the ocean at that depth exerted over six and a half million pounds on the bathysphere. Then in 1934 the pair dove to more than twice their previous record - 3,028 feet into the Atlantic; in his account of this feat in *One Half- Mile Down*, Beebe described the fantastic bioluminescent world that he witnessed in the dark of the abyss.[82]

William Beebe's pioneering efforts drew the attention of a Swiss physicist and inventor, Auguste Piccard. Dr. Piccard previously set an exploration record when he ascended nine miles into the atmosphere in a high-altitude balloon that he had devised in 1931. When he learned of Beebe's bathysphere, Piccard decided that a new challenge beckoned. He designed and tested a submersible bathyscaph (from the Greek *bathos scaphos*, deep boat) in 1937. Piccard's bathyscaph had no tether, making it independent of its support craft on descent and ascent and which also allowed the craft to land on the bottom. He improved upon Beebe and Barton's pressure sphere by making the walls thicker to allow descent to greater depths, by using gasoline tanks for buoyancy (gas is lighter than water), and through utilizing iron pellets for ballast that could be released to ascend. The craft amounted to an underwater version of a balloon, and Piccard named it *FRNS-2*, in honor of the Belgian sponsoring agency Fonds National de la Recherche Scientifique – the same sponsor for his high altitude experiments in the balloon he had christened *FRNS*. Dr. Piccard used newly developed transparent Plexiglas to make thick viewports for his bathyscaph, for his intent was to design a craft that might investigate the undersea world, not merely descend to depth to break an abstract

[80] Ibid., 162.
[81] Broad, *The Universe Below*, 57.
[82] Robert D. Ballard, *The Eternal Darkness* (Princeton: Princeton University Press, 2000), 13-32; Earle and Giddings, *Exploring the Deep Frontier*, 162.

record. The main limitation of the Swiss scientist's invention was that it had very limited lateral maneuverability; it moved primarily up and down, at times like a "runaway elevator."[83]

Pioneering efforts to explore the deep sea such as those by Beebe and Piccard were subject to the vagaries of independent sponsorship which presented limited opportunity to develop coherent research programs around platforms that amounted to scientific luxuries. And the technology that facilitated oceanographic inquiry as the depth envelope was pushed required better engineering and materials to withstand the rigors of the ocean environment - and correspondingly became more expensive to design and build. Auguste Piccard had developed his first bathyscaph under the sponsorship of the King of Belgium and his scientific advisory panel. When improvements became necessary, the King lost interest and Piccard sold the craft to the French Navy (where it was eagerly anticipated by a young French naval officer named Jacques Cousteau).[84] His appetite for deep diving whetted, Piccard cast about for funding from a number of private sources in Switzerland to build a new bathyscaph that improved upon his first design. His follow-on craft, *Trieste*, completed in 1953 and twice as large as Piccard's first effort was named for the Italian city that hosted its construction and whose citizens helped to sponsor its development and smooth the way for collaboration with the Italian Navy.[85]

Piccard and his son Jacques tested their new bathyscaph near Naples that summer with a dive of almost two miles to the sea floor. But for lack of funding, *Trieste* performed only a few more dives until 1957, when an agreement was struck that bound undersea exploration to the patronage of security interests even as it revealed secrets of the deep that had broad scientific relevance. *Trieste* was contracted to conduct oceanographic research dives by the Office of Naval Research (ONR) of the United States Navy. Of the fifteen dives the bathyscaph made under contract with the ONR, eight were for the purpose of studying the propagation of sound underwater.[86] The research branch of the Navy found the unique craft useful for testing a thesis that would further the development of a system for detecting Soviet submarines, the

[83] Ballard, *The Eternal Darkness*, 33-41; Broad, *The Universe Below*, 51-54; Jacques Piccard and Robert S. Dietz, *Seven Miles Down: The Story of the Bathyscaph Trieste* (New York: G. P. Putnam's Sons, 1961), 41-50.
[84] Ballard, *The Eternal Darkness*, 62.
[85] Piccard and Dietz, *Seven Miles Down: The Story of the Bathyscaph Trieste*, 45-58.
[86] Broad, *The Universe Below*, 51-52.

centerpiece of which was a program known within Navy circles as Project Caesar. Successful at exploiting long range transmission of underwater sound, Project Caesar enabled the early detection and tracking of Soviet submarines – a capability that proved critical in the undersea cat and mouse game of undersea warfare that persisted throughout the Cold War; although these efforts became public knowledge in broad terms in the mid-1960s, the details remained cloaked in secrecy for decades.[87]

In the wake of Columbus Iselin's description of the "afternoon effect" on underwater acoustic propagation paths, further research – and some element of serendipity – led to the discovery of phenomena known as a sound channel that formed at depth within a layer in the water column, and that focused and propagated sound energy for miles. Like the "afternoon effect," sound channels are caused by the refraction of sound, but in this instance temperature effects are complicated by pressure effects since these phenomena appear below the surface layer in deeper water. The upper boundary of the sound channel is the same strong thermal gradient at the bottom of the surface layer known as the thermocline that had "shielded" submarines during World War II from searching sonars by the manner that it refracted sound waves. But the sound channel's lower limit is a more amorphous depth not easily arrived at by looking at a BT trace as one might to determine the depth of the thermocline. In waters deep enough for pressure effects to overcome the downward refraction of sound toward the slower transmission speeds of colder waters, sound waves are caused to propagate back up the height of the sound channel toward the thermocline, where the temperature effect explained earlier regains the upper hand and renews this serpentine transmission path.

Under the right conditions, this oscillatory cycle continues such that the sound is trapped and steered by these counteractive influences within the layer and propagates for relatively long distances. Avoiding energy loss at the surface and at the seabed because the sound is constrained within a layer of the water column helps to prevent degradation of the signal. The sound channel thus described became known as the SOFAR channel, for SOund Frequency And Ranging, and through experimentation it was found that sound

[87] John W. Finney, "Secret Undersea System Guards U.S. Against Hostile Submarines," *New York Times*, September 14, 1965. All project names in this study are unclassified even if at one point they were part of classified programs, and all can be researched now in the open press.

sources could be tracked for hundreds of miles if they were within the layer where the sound channel formed. The SOFAR channel was theorized before World War II by Maurice Ewing while conducting further tests on the refraction of sound in water in relation to the "afternoon effect," utilizing a crude but effective technique akin to dynamite fishing. The potential for harnessing such acoustic phenomena for exploitation was enormous. In addition to the possibility it posed for extended range detection of submerged vessels, it was thought that the SOFAR channel might be utilized for long-distance communications between naval vessels, but the practical aspects of Ewing's theory were not fully vetted in time for use during the Second World War.[88]

Some twenty years after Ewing's explosive discovery, the *Trieste* experiments of the late 1950s contributed greatly to the refinement of knowledge about sound channels. Because of its ability to position itself stably at various depths in the water column, the bathyscaph was the optimal instrument to conduct the necessary experiments. And as a result of the great depth to which the submersible dove, a second sound channel was revealed that also focused energy, but in a layer much deeper than expected. The discovery and investigation of the sound focusing properties of sound channels subsequently enabled underwater target detection at ranges unheard of in the tactical sonar searches conducted by surface vessels with hull-mounted hydrophones. Long range propagation of sound via deep sound channels was the underlying principle behind Project Caesar, the U.S. Navy program that would decades later be revealed to the public and become more well-known by its originally-classified name: SOSUS (SOund SUrveillance System).[89] Initially designed to take advantage of the sounds emitted by snorkeling Soviet diesel boats, the system proved adept at monitoring the relatively noisy nuclear boats that the USSR subsequently deployed and thus became a critical element of the Cold War anti-submarine warfare effort of the United States.[90]

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[88] Weir, *An Ocean in Common: American Naval Officers, Scientists, and the Ocean Environment*, 172-178. Dynamite fishing relies on the explosion of dynamite underwater to kill nearby fish by the resultant compression wave. While not intending to kill marine life, Ewing exploded dynamite charges at depth to study the subsequent propagation of the compression (sound) wave. The SOFAR channel was utilized to design a search and rescue network in which shipwrecked sailors or downed aviators could drop explosive charges down into the SOFAR channel and their position determined via triangulation. Ewing's seminal work on long range sound propagation was published in two papers in *Propagation of Sound in the Ocean*, Memoir Series of the Geological Society of America, vol. 27 (Baltimore: Waverly Press, Inc., 1948).
[89] Broad, *The Universe Below*, 51-54.
[90] Edward C. Whitman, "SOSUS: The "Secret Weapon" of Undersea Surveillance," *Undersea Warfare*, Winter 2005.

Warships also were able to take tactical advantage of sound channels while operating independently by means of variable depth towed sonar systems that could be lowered down past the thermocline and into the sound channel to avail of their acoustic echo-chamber like qualities, but they tended to "have poor capability for open-ocean search and [were] essentially limited to localization, barrier, tracking, or trailing operations."[91]

SOSUS was a fixed system of hydrophone arrays that relied upon reasonably consistent ambient physical conditions for long distance low frequency sound propagation in the deep oceans where they were emplaced on the continental margins. They were the practical application that grew from a program known as Project Hartwell that had been established to investigate Ewing's sound propagation theories for their potential in undersea warfare. Research that was focused upon specific "tonal" frequencies such as those emitted by Soviet submarines fell under a classified project code- named Jezebel, the insights of which were subsequently wedded to further research into the long range propagation of low frequency sound conducted under Project Michael - a union which produced the underpinning for the broad-area undersea surveillance system (SOSUS) that was the focus of Project Caesar.[92] One tradeoff of such a fixed system design was that the SOSUS arrays were restricted in surveillance coverage as a result of the shielding and sound stripping effects of bathymetry, and by the requisite umbilical tether to shore stations that delimited where they might be mounted and monitored.

To provide flexibility, extremely long SURTASS (Surveillance Towed Array Sensor System) arrays were developed to take advantage of long-range low-frequency sound propagation in tactically relevant ocean regions as the Cold War submarine race wore on, and worked in tandem with the fixed SOSUS stations to provide targeting information to anti-submarine warfare assets. Although they offered some flexibility over the SOSUS arrays because of their flexible deployment, towed sonar arrays had their own collective Achilles Heel. Tow operations were problematic in some of the areas in the oceans where submarines frequented – either because of extreme environmental conditions that rendered surface ship

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[91] Donald C. Daniel, *Anti-Submarine Warfare and Superpower Strategic Stability* (Urbana: University of Illinois Press, 1986), 66-67.
[92] Finney, "Secret Undersea System Guards U.S. Against Hostile Submarines."; Whitman, "SOSUS: The "Secret Weapon" of Undersea Surveillance."

maneuvers useless or because of ever-shifting geopolitical sensitivities. While they had limitations, the fixed SOSUS arrays were around-the-clock monitoring systems. They were not subjected to the limitations imposed by high winds and seas at the latitudes where vessels with towed arrays were required to operate to improve chances for detecting Soviet submarines as they transited "chokepoints" such as the Greenland-Iceland-United Kingdom Gap (the GIUK Gap) on their way to patrol areas in the Atlantic off the eastern seaboard of the United States.[93]

Notwithstanding their individual strengths and weaknesses, between them the complementary techniques for exploiting the geophysical phenomena of deep sound channels offered unprecedented detection ranges against submarine contacts. And it was the greater understanding of the long-range propagation of sound in deep water from the *Trieste* experiments that had helped to develop both the Navy's towed array SURTASS "tails" and SOSUS ocean bottom arrays into one of the most potent - if not directly lethal – integrated systems in the undersea war. They served in effect as cueing assets, detecting Soviet submarines at still classified ranges and passing that information on to patrolling American surface ships, aircraft and submarines that would then attempt to shadow their adversaries for extended periods. These technologies required a thorough understanding of the propagation of sound at depth, and significant expertise about deep sea instrumentation to design, emplace and maintain the SOSUS installations. From a bureaucratic perspective that allocated assets towards demonstrated needs, the United States Navy possessed high priority validated requirements to know much more about the deep ocean environment to wage an effective undersea warfare campaign against a Soviet submarine threat that continued to improve until the final days (and then some) of the Cold War.

After the series of dives in the Mediterranean that it had contracted in 1957, the Office of Naval Research was pleased enough with the performance of *Trieste* to purchase the bathyscaph from the Piccards in 1958. It was decided that *Trieste* should be strengthened to enable even deeper dives to unlock the secrets of the furthest ocean depths. A new pressure sphere was built, one and one-half inches thicker than the original, and the windows were shrunk to about half the size to enable the bathyscaph to dive deep.

[93] Whitman, "SOSUS: The "Secret Weapon" of Undersea Surveillance."

And dive deep it did. In January 1960, with Jacques Piccard and U.S. Navy Lieutenant Don Walsh aboard, *Trieste* dropped 35,800 feet into the greatest known deep in the oceans, the *Challenger Deep* (named for the British oceanographic vessel that mapped it in 1951, itself the namesake of the 1870s warship that conducted the first extended oceanographic survey cruise). Unable to plant an American flag, Walsh left one lying on the bottom to mark America's exploration of the last frontier on Earth.[94] Piccard and Walsh made it safely back to the surface, but their success may have been pure luck. A viewport window in the access hatchway had cracked at depth (had it broken completely the craft could have foundered) and many instruments were damaged when *Trieste* was roughed up at the surface. The United States Navy had made its mark on the deep but retired *Trieste*'s deep diving sphere the year after. Although the *Challenger Deep* was later explored by a robot, no living person ever made it back to replicate Piccard's and Walsh's feat.[95]

The combat arm of the United States Navy thought that *Trieste*'s accomplishments were interesting, but without understanding the importance of her scientific discoveries largely considered that dabbling in the deep was more hobby than help in the Cold War. Admiral Hyman Rickover and the Bureau of Ships (BuShips) were not enthralled with any program that might siphon funds from the goal of an all-nuclear submarine combat fleet.[96] If the Navy in general was not enthralled with *Trieste* or deep sea research, a few men *were* interested in deep-submergence and kept the Navy in the game. Charles Momsen, a decorated submariner during World War II (and son of the inventor of the 1920s Momsen Lung), ran the Office of Naval Research undersea warfare branch. He was convinced that the work done by *Trieste* was worthwhile and agreed with the scientists and officers interested in going to the abyss that the Navy should retain and expand its deep submergence capability. If nothing else, the capability would help Navy's

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[94] Bernard L. Gordon, ed., *Man and the Sea: Classic Accounts of Marine Explorations* (Garden City: The Natural History Press, 1970), 281.

[95] Ballard, *The Eternal Darkness*, 59; Broad, *The Universe Below*, 54-55. A hero of ocean exploration, Don Walsh continues to dive to the deepest reaches of the ocean. Instead of doing so to push the envelope of deep diving technology – in essence, how could he - the former naval submariner now dives to expose others to the wonders to be seen in the deep, and to explore some of the famous marine archaeological sites scattered about the seas. A pioneer who never rested upon his laurels, Walsh wears his enthusiasm for deep sea exploration on his sleeve, and – from this author's personal experience – can tell riveting stories about his adventures in the deep.

[96] Broad, *The Universe Below*, 55-6; Sontag and Drew, *Blind Man's Bluff*, 48.

ongoing investigations into the propagation of low frequency sound in the deep oceans and the further installation of the "secret weapon" that came from this research: SOSUS arrays.[97]

At ONR Momsen was approached by the Reynolds Aluminum Company with a proposal to build an aluminum submarine, the *Aluminaut.* He knew that the Office of Naval Research could not build a research submarine itself, especially without running afoul of the Bureau of Ships, so he shopped the idea around to civilian oceanographic research labs. The first, Scripps Institution of Oceanography, turned him down. They wanted deep instrumentation, not a manned submersible. But Dr. Allyn Vine and Dr. Paul Fye of the Wood's Hole Oceanographic Institute weren't about to look a gift horse in the mouth. The Wood's Hole team joined with Reynolds to design Aluminaut, but it became a two-year effort in futility. Vine convinced Momsen to let his team seek other contractors to build the submersible. Momsen agreed and let a contract for the development of a vehicle that would be significantly different than a bathyscaph. It would be small and maneuverable. Instead of gasoline tanks for buoyancy, it would use the newly developed flotation known as syntactic foam – a hard resin filled with hollow glass spheres that could support a submerged ton with a block the size of a refrigerator. None of the larger defense contractors wanted any part of a project that went awry of BuShips and steered clear of the submersible. BuShips and other naval organizations funded research directly related to their military missions, but the latitude that ONR provided to the researchers it funded was a philosophy out of synch with the branch of the Navy that valued warships, warfighting, and few peripheral interests. Eventually Wood's Hole teamed with General Mills, the breakfast cereal company, whose engineering division wanted to dive in. Work began on the submersible, named *Alvin* in honor of Allyn Vine, in 1962.[98]

Navy traditionalists persisted in the thought that *Trieste*'s deep diving accomplishment and deep-submergence capability were merely extravagant boondoggles until tragedy struck. On the morning of April 10, 1963 *USS Thresher*, the Navy's newest and most advanced nuclear attack submarine augured into the depths on a test dive in the North Atlantic during a shakedown cruise after overhaul work at the Portsmouth Naval Shipyard. The last transmission from her 129-member crew was a garbled burst from

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[97] Broad, *The Universe Below*.
[98] Ballard, *The Eternal Darkness*, 70-3; Broad, *The Universe Below*, 56.

which surface observers could only make out a few words, "test depth." *Thresher* was lost. In addition to the personal tragedy it bore, the U.S. Navy was in for a public beating as well. It would take a number of weeks to find any conclusive wreckage to offer even the slightest evidence for *Thresher's* demise. The public wanted to know why - with what were assumed to be the most advanced capabilities in the free world available - the United States lacked the capability even to have attempted a rescue, and why later it could not find the remains of an entire nuclear submarine. At the same time, the Soviet Union wasn't about to miss an outstanding propaganda opportunity not very long after it had backed down from the Cuban Missile Crisis, and soon broadcast to the world that a nuclear reactor was now at the bottom of the Atlantic, poisoning the water.[99]

The U.S. Navy was powerless to find the wreckage in the ocean depths with the technology at its disposal in the fleet. By nightfall on the day of the accident, six warships, two submarines, and a sister submarine rescue ship to *Skylark* frantically searched the ocean but found only a small oil slick. Assistant Secretary of the Navy for Research and Development James Wakelin later explained why the Navy could not respond better to such an accident, "The Navy's fighting ships, because of the nature of the equipment they carry, could assist the search in only a limited manner. Research craft – our oceanographic ships – were the vessels most capable of investigating the area all the way to the ocean floor." [100] In the early light of April 11th, the submarine rescue vessel *Sunbird* encountered another slick in which floated small pieces of plastic and cork, and two rubber gloves of the type used to work on a nuclear reactor. Just over twenty-four hours after *Thresher*'s final garbled message, the Chief of Naval Operations broke the news to the American public, "So I conclude with great regret and sadness that this ship with 129 fine souls aboard is lost." While *Thresher*'s loss was acknowledged, little could be said about why she went down - or to what extent Soviet propaganda may have realized "blind pig finds corn" success. Secretary Wakelin's assessment was accurate. Almost immediately the Chief of Naval Operations "…ordered the bathyscaph *Trieste* from the West Coast to scan the depths…."[101]

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[99] Ballard, *The Eternal Darkness*, 75-80; Broad, *The Universe Below*, 56-60; Sontag and Drew, *Blind Man's Bluff*, 48-50.
[100] James H. Wakelin, Jr., "*Thresher*: Lesson and Challenge," *National Geographic*, June 1964, 761.
[101] "Farther Than She Was Built to Go," *Time*, April 19 1963, 27.

Trieste was loaded aboard an amphibious assault ship for the long journey from San Diego to Boston via the Panama Canal, but something needed to be done right away to answer the many questions surrounding the sinking of *Thresher* - not the least which was whether or not a nuclear reactor was indeed fouling the Atlantic Ocean. Other Navy-owned but university operated oceanographic research assets were distributed around the United States and deployed on research cruises; coordination of efforts would be an obstacle. Serendipitously, gathered in Washington at the Naval Research Laboratory in Anacostia were the directors of the major seagoing institutions that conducted oceanographic research for the Navy. By coincidence it happened that *Thresher* made her last dive on the day of the annual dinner of the United States Navy Research and Development Planning Council. Immediately the council members offered up assistance, and a technical advisory group of Navy and civilian scientists was established under the direction of the Office of Naval Research literally before a day had passed after the tragedy. At the same time one of the Woods Hole Oceanographic Institution's newest and most technologically proficient research vessels, *Atlantis II* (the successor to the *Atlantis* in which Columbus Iselin had cemented naval and ocean science interests when he investigated the "afternoon effect"), was quickly redirected from her current duties "to proceed at once to render all possible assistance in the search."[102] Two Navy-owned and university-operated research vessels close at hand, *Conrad* and *Gilliss*, were dispatched to the scene. Assistant Secretary Wakelin succinctly summed up the significance of what the Navy-ocean science collaborative brought to the otherwise neutered naval search effort, "Thus within hours after the tragic news, capabilities which had only recently been acquired as part of the national oceanographic program were ready to undertake the search."[103]

Through the efforts of the seagoing laboratories, an ad hoc flotilla of research vessels and cobbled together oceanographic instruments quickly put to sea. Even with the state-of-the-art equipment these vessels brought to the search, it would not prove an easy task. *Thresher* had sunk in over 8,000 feet of water on the edge of the continental slope east of Georges Bank in a region not known for the calmest of seas in April. Towing operations with long cable lengths were always risky; in rough seas they could be

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[102] Robert Frosch, interview by author, telephone conversation and electronic mail correspondence, Cambridge, MA., 20 April 2005; John B. Hersey, "Thresher Search," *Oceanus*, September 1963.
[103] Wakelin, "*Thresher*: Lesson and Challenge."

downright dangerous and run a high risk of losing the towed "fish." What is more, at that time navigation was still somewhat of an art, requiring interpretive skill to determine one's position even with the assistance of radio navigation. The precision required for searching the ocean floor more than a mile below was – to put it mildly – a challenge. Not only was it a difficult thing to fix the position of the search vessel, but the ocean scientists were required to estimate the relative position of the gear they towed on cables that stretched down to the ocean floor a fair distance behind the ship, with uncertainty compounded all the while by the unknown catenary in the tow cable. As frustrating as this effort was already it was conducted under a good deal of pressure to discern *Thresher*'s fate, and not only for the political importance of the event as the world – and the Soviet Union in particular – watched the foremost Navy at sea loiter fecklessly as its most advanced submarine remained lost in the depths. There was a compelling human drama as well; back in Portsmouth, New Hampshire anxious families waited by telephones in shock over an event the peacetime Navy had not experienced in kind since 1939 when the submarine Squalus sank while also conducting test dives off the New England coast. That accident occurred in shallow coastal waters and many of the crew were saved using technology only slightly more sophisticated than the diving bells in use since the time of Alexander the Great. Although almost twenty five years had passed and technology had improved dramatically, regrettably there was nothing that could offer even the slightest glimmer of hope for rescuing a crew whose exact fate remained a mystery shrouded by a mile of the cold North Atlantic.

In the rush to demonstrate some measure of success in this thrown-together naval search effort, a picture that a tow camera snapped of the search ship's anchor was embarrassingly broadcast to the world as the lost submarine, and the Navy was quickly forced to recant.[104] But by late May wreckage was localized via the use of a towed magnetometer, and pictures of debris photographed by cameras deployed by WHOI's *Atlantis II* were released to the press as strong indicators of *Thresher*'s fate. Packages of neoprene "O" rings positively identified as *Thresher* inventory were dredged by the Lamont Laboratory research ship *Conrad* on May 28th and photographs of these items were released four days later.[105] Other sensors including underwater television, precision depth-recording sonars, and electrodes that could detect electric

[104] Ballard, *The Eternal Darkness*, 75-80; Broad, *The Universe Below*, 56-60.
[105] Frosch, interview 20 April 2005; Hersey, "Thresher Search." Pictures of these artifacts with accompanying Navy press release information may be viewed online at the naval archives: http://www.navsource.org/archives/08/08593/htm.

currents in seawater that were induced by dissimilar metals were employed, along with underwater Geiger counters to seek radiation emitted by *Thresher*'s nuclear reactor. Fortunately the search "…obtained meaningful results from all the detectors except the Geiger counters. They never did indicate any abnormal radiation levels."[106] In June, *Trieste* arrived on scene and quickly augmented the work already accomplished by the naval research scientists. The bathyscaph photographed and recovered bits of wreckage from the destroyed submarine and then on her eighth dive, five months after *Thresher* was lost, *Trieste* located the primary wreckage field. U.S. Navy Lieutenant Commander Don Keach, *Trieste*'s pilot, described the awful scene just outside the thick plexiglass viewport, "Battery plates, lead ballast, shredded cables, sections of superstructure – the bottom was a mass of debris everywhere we looked. There could be no question – this was *Thresher*."[107]

Within weeks of *Thresher*'s loss the Navy formed the Deep Submergence Systems Review Group, a panel of experts that recommended the Navy develop the technology to rescue imperiled personnel at depth, to investigate and recover objects from the ocean floor, and to salvage submarines. The report was as much for internal Navy consumption as was the laundered conclusion subsequently made public to the American people that detailed the planned development of Deep Submergence Rescue Vehicles that could rescue submarine crews trapped on the bottom - the loss of *Thresher* was doing nothing to help recruit new submariners.[108] Public, government, and commercial interest was aroused by the *Thresher* tragedy. Acknowledging its inadequacy in this arena, even before the Deep Submergence Systems review group published their recommendations the Navy took steps to improve its underwater capability. Work continued on *Alvin*. Underwater robots were developed. An improved version of the Navy's only bathyscaph was commissioned as *Trieste II*. With the sudden emphasis on deep submergence that heralded a new source of funding, Admiral Rickover, father of the nuclear submarine, found religion and forced through plans to build *NR-1*, a nuclear powered research submarine that could carry a crew of seven, remain submerged for weeks, and possessed wheels to move along the ocean bottom. The Navy announced plans for two Deep Submergence Rescue Vehicles (DSRVs), *Mystic* and *Avalon*, that would be

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[106] Wakelin, "*Thresher*: Lesson and Challenge," 762.
[107] Donald L. Keach, "Down to *Thresher* by Bathyscaph," *National Geographic*, June 1964, 775.
[108] Ballard, *The Eternal Darkness*, 80-3; Broad, *The Universe Below*, 57-9.

transportable by truck, boat or airplane to any location in the world in a matter of hours, able to reach down 2,000 meters, mate a rescue hatch with that of a disabled submarine, and ferry 24 crewmen to the surface at a time.[109] Assistant Secretary of the Navy Wakelin wrote an article in *National Geographic* to tell the nation about the advances being made beneath the waves, about the fantastic new submarine rescue systems under development, and how the Navy's interest in the deep ocean would benefit civilian research in oceanography as well.[110]

The importance of the Navy's augmented - and public - investment in marine science and technology was underscored not long after the loss of *Thresher*. *Alvin* and the ONR-sponsored remote vehicle *CURV* (Cable-controlled Underwater Recovery Vehicle) were thrust into action at the earliest stages of their operational capability on a matter of critical importance to national – and international – security. High above coastal Spain near Palomares, an American B-52 bomber and an aerial refueling tanker failed the big sky theory and the basic premise of physics that two objects cannot simultaneously occupy the same space. In the process four hydrogen bombs carried by the Stratofortress plummeted earthward. Three impacted the ground and initiated a large remediation effort to ensure containment of any possible radioactivity from the materials that made up the explosive core of the bombs. The fourth bomb however, drifted seaward in its parachute and was reported to have splashed into the sea by a local fisherman. Until it was recovered some eighty days later, the world watched from the edge of its seat (the Soviet Union was cheering in the aisles) wondering if Spain, Portugal, and a few other countries would be incinerated – not a public relations coup for the United States. *Alvin* found the nuclear needle in a haystack; *CURV* attached the recovery lines and then was deliberately driven into the shrouds of the parachute attached to the weapon in order to keep it from sliding off an undersea cliff. The tangled mass of line and parachute that reached the surface wrapped around *CURV* dangled below it a weapon that possessed seventy times the destructive power of the bomb that leveled Hiroshima.[111]

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[109] Ballard, *The Eternal Darkness*, 82-6; Broad, *The Universe Below*, 59-61.

[110] Ballard, *The Eternal Darkness*, 82-86; Broad, *The Universe Below*, 59-61; Wakelin, "*Thresher*: Lesson and Challenge."

[111] Broad, *The Universe Below*, 65-8; Gardner Soule, *Undersea Frontiers* (Chicago: Rand McNally and Company, 1968), 162-74.

The nascent deep submergence capability and the liberal patronage of ocean scientists in which the Navy had invested via the Office of Naval research rapidly were proving their worth. Oceanography and ocean technologies became established core competencies within the United States Navy. After another submarine tragedy in 1968, the advanced bathyscaph *Trieste II* descended miles into the Atlantic to survey the broken hull of *Scorpion*, the second nuclear attack sub lost by the United States. For months after the submarine failed to return to its homeport the crew's families and the rest of the Navy had watched and waited. Speculation over *Scorpion's* demise ranged from engineering defects similar to those thought to have doomed *Thresher*, to a hot-running torpedo or even worse, a Soviet attack. Utilizing data from some of the deep sea hydrophones that the United States had placed on the ocean floor as part of Project Caesar, *Scorpion*'s death throes were reconstructed according to the echoes of successive implosions that occurred as the vessel plummeted past crush depth. Critically this information also confirmed the submarine's fate was a solitary one; no foreign submarines were detected near *Scorpion* when her mortal wounds were inflicted. Triangulating information from different stations provided an area to concentrate search efforts, correctly predicting where the doomed vessel was thereafter located. The deep-sea tools of *Trieste II* were not able to change *Scorpion's* fate (the precise cause of which is still a matter of debate), but at least for the relatives of the crew the expedition provided some visual measure of closure.[112]

The Naval Intelligence Community also saw opportunity in the wake of the *Thresher* tragedy. Intelligence officers, inspired by the success of deep submergence vessels in locating the downed submarine, wanted to know if it was possible to locate - and maybe even recover - the pieces of fallen Soviet missiles that they had been diligently tracking to splashdown for years. Design parameters of nosecones and warhead payload capacity could tell not only about Soviet capability, but even something about the strategy behind their designs – whether they intended to use precision weapons that inferred they were targeting U.S. missile sites and leaving open the possibility of first-strike, or blunt force area weapons that represented the city-destroyers of deterrence strategy…and these insights might be gleaned from the shards scattered about the seafloor. Although an enormous challenge, the Deep Submergence Systems

[112] Broad, *The Universe Below*, 76-77; John P. Craven, *The Silent War: The Cold War Battle Beneath the Sea* (New York: Simon & Schuster, 2002), 198-203.

Project (DSSP) director thought it possible.[113] The few submersibles in the Navy inventory and those currently under development required surface ship support and were not yet up to the task. They could never penetrate Soviet waters to execute what the Intelligence Community desired. But a specially configured submarine could. The DSSP found the perfect submarine for the job, *USS Halibut*. The only nuclear powered submarine of the *Regulus* missile program, *Halibut* had a huge hangar called the "bat cave" by her crew that was just what was needed for "special projects." *Halibut* went through an overhaul that turned her into a spy boat. Special "fish" with cameras and sonar were developed that could be towed miles below the sub on a cable extended from a hole cut in *Halibut*'s hull. The project was a departure for the submarine force. The technology that was developed to outfit *Halibut* was more akin to the technologies that enabled deep submergence vehicles to dive far deeper than the crush depth of a conventional submarine. The Navy learned as it went with the deep diving gear, determining how great depth affected instrumentation the hard way. But it persevered and *Halibut* went on to accomplish some of the greatest deep-sea intelligence exploits of the Cold War.[114]

The Deep Submergence Systems Project had handed the submarine community an entirely new clandestine mission. Although it was not a public one, such as the submarine's acknowledged roles as an attack platform against enemy vessels and as an integral leg of the nuclear triad, it was invaluable throughout alternating periods of confrontation and détente with the Soviet Union. Vital intelligence was gained that alleviated some of the tension over strategic weapons numbers and capabilities. Soviet communications cables were successfully and repeatedly tapped in different oceans within spitting distance of opposing military forces when deep divers locked out of submarines and submersibles in treacherous conditions to conduct the dangerous wiretap missions. The Soviet missile shards Naval Intelligence sought at the bottom of the sea - debris from the launches the Navy had at first hoped to only surreptitiously monitor with post-WWII snorkel-equipped diesel boats in the days that they hazarded the attendant danger of holddown in Soviet waters - were located, photographed, and in some cases recovered, providing

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[113] Sontag and Drew, *Blind Man's Bluff*.
[114] Broad, *The Universe Below*, 63-93; Roger C. Dunham, *Spy Sub* (Annapolis: Naval Institute Press, 1996); Sontag and Drew, *Blind Man's Bluff*.

incalculable intelligence on the Cold War adversary's capability.[115] Enormously risky and only now public in sketchy detail, these were individual victories that helped shift the balance over forty years to win the Cold War. None would have been possible without the original interest the Navy nurtured in deep submergence with the contract trials and subsequent purchase of *Trieste*. And justification for such a gamble on a scientific "luxury" like a bathyscaph was based upon the importance of underwater acoustic research that was conducted in earnest just prior to World War II as a function of undersea warfare. By the end of the 1960s, having gone to the well on three major public operations (*Thresher*, the H-bomb, and *Scorpion*) and untold secret missions, the United States Navy was firmly committed to marine science and technologies and attendant specialized deep submergence capabilities. The submarine threat of the Soviet Union unintentionally spurred greater American interest in oceanography as a scientific discipline, a field which might easily have languished after World War II had a threat not emerged to keep it central to security interests.

"Take Her Down…" into The Silent World 20,000 Leagues Under The Sea Around Us[116]

From its first introduction, undersea warfare threw traditional naval thinking into disarray. The earliest effective tactical undersea vehicles and weapons that debuted in the United States Civil War dramatically demonstrated a new method of warfare that could be waged against stronger naval power. Although the Confederacy was defeated in this conflict, these novel tactics of naval warfare were never effectively

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[115] Broad, *The Universe Below;* Dunham, *Spy Sub;* Sontag and Drew, *Blind Man's Bluff*.

[116] "Take Her Down" was the dying order of Commander Howard Gilmore of the U.S. submarine *Growler* on February 7, 1943. Having rammed the Japanese vessel *Hayasaki* while running his submarine on the surface, Commander Gilmore was wounded by ensuing gunfire from the vessel. His final order from the exposed conning tower was obeyed and *Growler* dove to fight another day; her dead captain earned the Congressional Medal of Honor for his self-sacrifice and his last words entered the lore of submarine warfare. Jules Verne's 19th century classic *20,000 Leagues Under the Sea* introduced the world to the potential of the submarine. Incorporating up to date ocean science of his day to add to the realism, Verne intuited submarine technology and operations with eerie prescience. Rachel Carson's 1951 *The Sea Around Us* informed the public about the advances made in oceanography during World War II and established the author as a best-selling writer – in the process laying the foundation for her later catalytic treatise on anthropogenic threats to the environment. Jacques Cousteau's first book *The Silent World* introduced the wonders of the undersea environment through vivid photographs and launched his career as a marine educator. His follow-on publications and his popular television show about his adventures exploring the oceans from his vessel *Calypso* imparted incalculable influence on future oceanographers and the general public as environmental awareness - especially in the oceans - blossomed in the 1960s and 1970s.

countered and gave the United States Navy considerable pause through the realization that such methods could largely neutralize its power under certain circumstances. By World War I the technology of undersea warfare had improved enough to constitute an open sea threat rather than the coastal, harbor and riverine threat posed fifty years earlier by Confederate "infernal machines" in the United States. Naval strategy was again rocked when this threat proved capable both against the conventional naval power represented by large-gunned capital ships, and by perfecting the previously looked-down-upon strategy of *guerre de course* against merchant shipping in the Great War. It was during this conflict that the first intimations manifested that naval warfare had transcended its historical dimensional constraints…in more ways than one. No great powers of observation are required to note that submarines operate at various levels of the water column rather than only on the surface like conventional vessels – in the process expanding the naval battlespace to three degrees of freedom. Yet more subtly and critically undersea warfare had pierced a fourth dimension, one that might be considered the *geophysical battlespace* because of the need to enlist the physical sciences operationally for tactical warfighting advantage. However, World War I was winding down by the time that scientific theory was efficiently becoming translated to practical means, and the technology of that era's undersea weaponry was not of the caliber to fully compel the issue irrefutably to the fore. This would not be the case in World War II and the Cold War that followed.

By the outbreak of the Second World War, more capable submarine technology and improved weapons were married to tested operational doctrines that made undersea warfare an essential part of naval strategy from the outset. At this stage ocean science proved a more valuable partner, and demonstrated operational impact in both offensive and defensive undersea warfare. But the submarine as a weapon of war had yet to reach its pinnacle of design… That zenith was reached once undersea warfare morphed from tactical importance during World War II to strategic significance at the highest levels of national security throughout the Cold War when nuclear-powered ballistic missile submarines patrolled the depths. It was at this juncture that ocean science proved to be indispensable to security interests. Oceanographic discoveries appeared in lockstep with security imperatives: the explanation of the "afternoon effect" exploited by fleet submarines in World War II; the discovery of deep sound channel acoustics and the development of SOSUS arrays and towed variable depth sonars that proved so critical against the Soviet submarine fleet in

the Cold War; deep submergence capabilities that leveraged the bathyscaph and inspired follow-on deep sea technologies and proved invaluable in the submarine tragedies of *Thresher* and *Scorpion*, for the recovery of the H-bomb near Palomares, and provided dramatic intelligence coups with respect to Soviet missile technology and the tapping of Soviet operational communications traffic.

Oceanographers made possible a warfighting strategy against an otherwise largely invisible and incredibly dangerous adversary. But that was not all… As fundamentally important as these developments were to naval operations and national security, the application of ocean science to the problems of undersea warfare also unlocked other secrets of the sea - discoveries which unleashed forces that held profound implications for security and many other aspects of international relations on a scope never before witnessed. Set in motion, these were forces as unstoppable as the tides, despite the maneuverings of even the most powerful among nations of the world. Endeavoring to lift the veil that cloaked the ocean depths, and using all of the tools in the toolbox that had been developed to investigate the oceans in support of undersea warfare, scientists "rediscovered" one of the findings catalogued almost a hundred years earlier on the bottom of this most opaque of realms. Once revealed and reassessed using modern technologies that provided insights unavailable back when specimens were first dredged up into the light of day, this re-discovery inspired a modern day treasure hunt for the mineral resources of the deep sea. Earlier in the century this might have facilitated another colonial-like exploitation by technologically capable states, but at just the right time in the history of nations it triggered an unexpected series of events. Dramatically presented to the United Nations as a panacea for ailing developing economies, the subsequent intense interest in the riches of the deep seabed compelled almost all of the states of the world to the negotiating table for more than ten years to attempt what historically had proved unattainable: the formulation of universal and binding laws for the boundless seas.

The Buck Starts Here…

It is likely that President Harry Truman thought he was acting in the best interest of the United States when he issued the Proclamation on the Continental Shelf of 1945, proclaiming jurisdiction over the natural

resources of the shallow seabed region contiguous to U.S. shores. The purpose, after all, was "to facilitate conservation of shelf resources, to provide protection against foreign exploitation of those resources, and to promote domestic investment in offshore mining by assuring U.S. industry security of tenure."[117] Nevertheless, Truman's proclamation unintentionally instigated a series of similar assertions around the world that were likened to "the colonial division of Africa a century earlier."[118] Some countries took this initiative to the extreme. Chile, Ecuador and Peru signed the Declaration of Santiago extending "their jurisdiction and sovereignty over the sea, seabed, and subsoil out to a distance of 200 miles from their coastlines."[119] It became evident that some degree of uniformity was necessary to clarify the multitude of differing territorial and economically exclusive claims made successively by the coastal nations of the world. To that end, the 1958 United Nations Law of the Sea Convention on the Continental Shelf was formulated in Geneva to set an internationally acceptable limit to national assertions.[120] The Conference decided that coastal states should exert exclusive control over the resources of the continental shelf contiguous to their shoreline "to a depth of 200 meters or beyond that limit, to where the depth of the superadjacent waters admits of the exploitation of the natural resources of the said area."[121] With a definition that exquisitely ambiguous, the matter was far from settled… .

Even with its brief tenure among nation-states, the United States had a history of creating a ripple effect over the designation of territorial waters. Ever since the Dutch jurist Hugo Grotius issued his seminal treatise *Mare Liberum* in 1608, there had long been a strong sentiment of the freedom of the seas, which could be "neither seized nor enclosed." [122] In spite of this tendency, Thomas Jefferson – while attempting to reign in privateering off the coast of the newly formed United States - declared a three-mile jurisdictional limit in 1793.[123] The three-mile limit was not merely an arbitrary figure; it was based on an informal

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[117] Jack N. Barkenbus, *Deep Seabed Resources* (New York: Free Press, 1979), 30; Ann L. Hollick, "U.S. Oceans Policy: The Truman Proclamations," *Virginia Journal of International Law* 17, no. 1 (1976).
[118] Jon Erickson, *Marine Geology: Undersea Landforms and Lifeforms* (New York: Facts on File, Inc., 1996), 152.
[119] David A. Ross, *Opportunities and Uses of the Oceans* (New York: Springer-Verlag, 1980), 43.
[120] Barkenbus, *Deep Seabed Resources*, 31.
[121] 1958 Geneva Convention on the Continental Shelf in Shigeru Oda, *The International Law of Ocean Development: Basic Documents* (Leiden: A.W. Sijthoff International Publishing Company, 1972).
[122] Hugo Grotius, "*Mare Liberum* (1608) Van Deman Magoffin Translation," in *Man and the Sea: Classic Accounts of Marine Explorations*, ed. Bernard L. Gordon (Garden City: The Natural History Press, 1970).
[123] Jonathan Bartlett, ed., *The Ocean Environment* (New York: H.W. Wilson, Co., 1977), 167-8.

practice among some nations of Europe that went by the somewhat tongue-in-cheek moniker of "the cannonball principle." Attributed to the Dutchman Cornelius Bijnkershoek, this practice asserted that a state could claim seaward jurisdiction as far as shore-based cannon could fire – in his time about a marine league which was roughly three miles.[124] Many nations followed Jefferson's lead and established three-mile territorial seas although the demarcation as a general norm of international law was never ratified by formal agreement. There were apparently no concerted efforts to extend the three-mile limit as technology improved the range of cannon until Truman stirred the waters.[125] In a sense there was no need. Traditional fishing grounds at some considerable distance from the shore or even overseas could be – and were – matters of contention between states to be handled diplomatically, even if that proved to be diplomacy via grapeshot; but the cannonball limit of nearshore sovereignty provided for the basic defensive needs that led to its "establishment" as a practice of coastal nations.

In general, exploitable seabed resources were close ashore industries, including seabed mineral resources that were exploited by tunneling below the seafloor via shafts that began on land. As forward-looking as governments and legal counsels might have been, the dearth of knowledge about what lay beneath the seas precluded substantive interest – and therefore need - to attempt to legislate jurisdiction over this unseen unknown portion of the maritime realm. In practice, much of what related to attempts to establish arbitrary political boundaries for the seas depended not upon marine resources, but upon exploration and discovery – and that was made possible by advancements in marine technologies. During the Age of Exploration the impetus was the discovery of riches *beyond* the seas that came as a result of navigational improvements and vessel design; after the Truman Proclamation it occurred because of riches *beneath* them discovered and made exploitable by the technical innovations developed to wage undersea warfare. The importance of technology is evident in the very boundary definitions themselves that appear in the successive development of maritime law; although they prescribe for different reasons of defense and economic exploitation, the jurisdictional limits decided by the cannonball principle and by the 1958 Convention on the Continental Shelf are both based on contemporary technical state-of-the-art: the range of a 17th century cannon, and the engineering ability of nations in the 1950s to exploit the ocean bottom to the

[124] Ross, *Opportunities and Uses of the Oceans*, 39.
[125] Ibid.

limits of the continental shelf. Both of these definitions, therefore, dependent as they were on “state-of-the-art” were inherently vulnerable to change.

The Law of the Sea Conference at Geneva in 1958 also promulgated three additional conventions concerning the high seas, territorial seas, and fisheries, but in some ways they complicated matters as much as they sought to codify common practice. The Pandora’s Box that President Truman opened issued forth an unwanted corollary to the extant concept of a territorial sea: a region called a contiguous zone was established that began at the seaward edge of the territorial sea and stretched out to an imaginary boundary twelve miles distant from the coastline. Unfortunately, the negotiated definition for the *territorial sea* established by the convention was vague; and in addition the rights accorded coastal nations to take various autonomous actions within the newly prescribed contiguous zone initiated a strong argument that territorial seas could in practice be extended out to twelve miles - a prospect that the United States did not want to happen.[126] There was a certain convenience in ambiguity with respect to precise limits on territorial seas, especially for nations that were maritime powers. And as one of these naval powers, the United States possessed interests far beyond the exploitation of living and mineral resources - the rationale that drove many of the extended claims of national jurisdiction following the Truman Declaration.

After World War II, even as the United States began to draw down its immense naval forces, it still emerged as one of the most powerful maritime nations. When the Cold War developed immediately after the end of WWII, the United States committed to a foreign policy that sought the containment of Soviet communism. And as the consequent superpower confrontation expanded worldwide via political and military influence, it was apparent that the ability to project power and influence over such a large stage depended in part upon a strong naval presence and the freedom of movement through the oceans to move men, materiel and weapons to regions of the world distant from U.S. territory. Limits to the ability to project naval power then were undesirable, and extensions of territorial seas might interfere with this - especially in areas regarded as “strategic chokepoints” that would fall under national jurisdiction if that sovereign boundary of the territorial sea were allowed to extend seaward as far as the twelve mile limit of

[126] Ibid., 44.

the contiguous zone implied. Although certainly unintentional, through its own development of ocean science and ocean technology (as a function of the challenges of undersea warfare) that subsequently made exploitation of the seabed more feasible - and then to boot by the political impetus imparted by President Truman - the United States had set this very process in motion. Even this unexpected sequence of events did not completely describe the irony of the situation. The U. S. prided itself for being a democratic nation of laws, and espoused this founding philosophy as the answer to authoritarian communism; yet because of its efforts globally to oppose the dictatorial autocracy it saw as the ultimate intention of the communist elite, the United States was not particularly enthralled with becoming yoked by a universally respected Law of the Sea that constrained the ability to project its naval power.

"Yet still his claim the injur'd ocean laid,

And oft at leap-frog ore their steeples play'd:

As if on purpose it on land had come

To show them what's their mare liberum*."*

– Andrew Marvell, The Character of Holland[127]

The collection of norms that comprises the Law of the Sea has long been as fluid as the oceans, adapting to forces exerted upon it but maintaining some semblance of continuity in the larger scheme. Traced back to the earliest seafaring day of ancient Rome, maritime law demonstrates the dichotomy of law and power politics. From a natural law perspective, Romans such as Cicero, Ovid and Virgil saw the waters and the shores of the sea as open to all, because no men could possess such a vast uncontrollable expanse. Yet the Romans referred to the Mediterranean as *Mare Nostrum – Our Sea* – and did their best to exert control over the lands that surrounded it and by extension the sea itself.[128] Alternately thereafter through the ages the seas became subject to claims of sovereign control by some emergent power, and then to counter assertions that no one entity could arrogate such dominion over something common and available to all those who

[127] Andrew Marvell, "The Character of Holland *(1653)*," 2001 (accessed April 27, 2001); available from http://www.geocities.com/~spanoudi/poems/marvel01.html.
[128] John P. Craven, "The Evolution of Ocean Policy," in *The Law of the Sea in the 1990s: A Framework for Further International Cooperation*, ed. Tadao Kuribayashi and Edward L. Miles (Honolulu: The Law of the Sea Institute, 1992); Richard T. Robol, "Maritime Law in Classical Greek and Roman Literature," *Journal of Maritime Law & Commerce* 31, no. 4 (2000).

demonstrated the courage and wherewithal to venture upon its surface. These of course, were the opposing perspectives of peoples who thought they might effectively assert control versus competing parties that sought access for their own interests. The most noted of these claims include the famous division of the world oceans by Papal Bull in 1493 between Spain and Portugal. The timing of Pope Alexander VI's decree is entirely – politically - significant. For many years prior to this edict, Portugal had been incrementally working south around the African coast on successive voyages to find a way to the spices of the Orient.[129] Then in 1492, flying the Spanish flag, Christopher Columbus made a rather significant discovery to the West. The Pope sought to avoid conflict between these Catholic kingdoms and to limit the potential for either to become too powerful with respect to the other. In addition to sovereign claim to any lands discovered in their respective hemispheres, Spain and Portugal were also granted license to administer all seagoing trade in these regions - monopolies the Catholic kingdoms vigorously enforced while strong enough to do so.[130] In the seventeenth century, a rising maritime power sought to break this monopoly, and engaged the brightest legal mind it could enlist to undermine justification for such overreaching jurisdiction, even if it had been granted by an earthly representative of Divine power.

In his treatise *Mare Liberum* the Dutch jurist Hugo Grotius persuasively argued the positions of the ancient philosophers, natural law, and the law of nations against the proposition that the seas might be possessed as a matter of edict. "All property…is based upon possession or occupation, which requires that all movables shall be seized and all immovables shall be enclosed; things which cannot be seized nor be subject to enclosure may not become property: they are common to all, and their usage pertains to the entire human race rather than a particular people."[131] Even earlier, in 1580, England under Queen Elizabeth had similarly espoused the view that "the sea and the air were open and free to all mankind, and that no exclusive rights in them could be obtained by given nations or individuals."[132] That was, of course, a convenient stance for Britain until ascendant British sea power opposed maritime operations of Dutch

[129] Craven, "The Evolution of Ocean Policy."; J. B. Hewson, *A History of the Practice of Navigation* (Glasgow: Brown, Son & Ferguson, Ltd., 1951), 12-13; Derek Howse and Michael Sanderson, *The Sea Chart* (New York: McGraw - Hill Book Company, 1973), 27.
[130] Michael Marshall, *Ocean Traders: From the Portuguese Discoveries to the Present Day* (New York: Facts On File, 1990), 32.
[131] Quoted in Erin Bain Jones, *Law of the Sea: Oceanic Resources* (Dallas: Southern Methodist University Press, 1972), 9.
[132] Quoted in Ibid., 10.

fishing and merchant fleets in the 17th century, and England employed the talents of the jurist John Selden to argue the opposite side of the coin. Selden's *Mare Clausum* alleged that sovereigns had a right and duty to exert control over waters adjacent to their domains – i.e. the English monarch was empowered to keep the Dutch fishing fleets away from "traditionally" British fishing grounds, as well as to obstruct Dutch maritime traffic in the Channel. These were fundamental duties of a sovereign in protecting his lands from invasion and providing for the economic security of maritime fisheries and trade, and indeed – Selden asserted - had been long the practice in England and recognized by others.[133] Selden's rather biased viewpoint established a toehold for the notion of territorial seas near coastlines, but the high seas were repeatedly assessed by jurists thereafter as common to all men. This state of affairs was not counterintuitive, but contentious nonetheless because no firmed fixed boundary was established as to what encompassed the *territorial sea* and what was properly considered the *high seas*. With some exceptions, this boundary existed somewhere about the extent of one marine league – about three miles – offshore, but precise limits were not universally established. This conundrum remained unchallenged until ocean science evolved to the point that the vagaries of such concepts could no longer be condoned.

The advances in oceanography that were accomplished during and after the Second World War to prosecute a strategy of undersea warfare influenced the way nations viewed the oceans, ocean resources, and their own sovereignty. These perceptions continued to evolve as scientific investigation of the sea floor in support of naval interests collaterally discovered new resource deposits, and marine technology innovated methods to recover them. As a consequence, the 1950s saw the emergence of international attempts to codify relationships of ocean governance and the management and exploitation of ocean resources. As described earlier in this study, the United States played a prominent role. Proclaiming concern for the "conservation and prudent utilization" of the resources of the continental shelf that might possibly satisfy a "world-wide need for new sources of petroleum and other minerals," President Truman issued his declaration asserting that United States interests required "recognized jurisdiction." He further stated that the United States regarded "the natural resources of the subsoil and sea bed of the continental

[133] Sayre A. Swarztrauber, *The Three-Mile Limit of Territorial Seas* (Annapolis: Naval Institute Press, 1972), 18-22.

shelf beneath the high seas but contiguous to the coasts of the United States as appertaining to the United States, subject to its jurisdiction and control."[134]

The Truman Declaration of 1945 asserted U.S. control over the seabed and subsoil of the continental shelf, even in areas beyond the three miles the United States then claimed as territorial seas, but did not claim the water superadjacent (above) the shelf in these regions to avert controversy related to the historically-based "rights" of other nations to operate vessels on the "high seas." A press release issued with the proclamation described the limits of the continental shelf as "submerged land which is contiguous to the continent and which is covered by no more than 100 fathoms (600 feet) of water…."[135] The marked change in grade that defines the break between the continental shelf and the seaward continental slope that leads to the deep ocean floor marks roughly the shoreline of an ancient lower sea level. The 100 fathom line was convenient for a consistent approximation of this shelf-slope boundary, but the natural extension of the continental land mass can vary for a number of geological reasons such that this interface may be found up to three times as deep.[136] Traditional economic interests over living resources of the seas - primarily fisheries – that previously had instigated various international conflicts were now joined with equal attention by the non-living resources of the seafloor and subsoil of continental shelves.[137]

President Truman's declaration was prompted by a growing domestic desire to exploit the oil resources discovered on America's seaboard when seismic and other marine technology developed for the war effort enabled oil companies to prospect offshore in increasingly deeper areas. Marine hydrocarbon resources had long represented great potential just out of reach. Domestic political constituencies with interests in the extension of national jurisdiction lobbied for protections that would provide them security to invest in offshore exploration and drilling. President Truman subsequently acted in the best interest of the United States (and its domestic political lobbies) "to facilitate conservation of shelf resources, to provide

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[134] Proclamation by President Truman of 28 September 1945 on Policy of the United States With Respect to the Natural resources of the Subsoil and Sea Bed of the Continental Shelf in Oda, *The International Law of Ocean Development: Basic Documents*, 341.

[135] White House Press Release, September 28, 1945 in Marjorie M. Whiteman and Green Haywood Hackworth, *Digest of International Law* (Washington: U.S. Government Printing Office, 1963).

[136] Ross, *Introduction to Oceanography*, 249-274; Louis B. Sohn and Kristen Gustafson, *The Law of the Sea*, Nutshell Series (St. Paul: West Publishing Company, 1984), 153-159.

[137] Wolfgang Friedmann, *The Future of the Oceans* (New York: George Braziller, Inc., 1971), 19-20.

protection against foreign exploitation of those resources, and to promote domestic investment in offshore mining by assuring U.S. industry security of tenure."[138] However, Truman's words did not fall on deaf or unresponsive ears - unilateral action of such magnitude by a rising world power could not take place in a political vacuum. Where nominal territorial seas had long been supported – if undefined - by international law, countries emboldened by the United States "land" grab asserted their own extended territorial rights - some taking this initiative to the extreme. Chile, Ecuador and Peru signed the Declaration of Santiago extending to each "sole sovereignty and jurisdiction over the area of sea adjacent to the coast of its own country and extending not less than 200 nautical miles from the said coast."[139]

The waters bordering the western coast of South America overlay an area where the seafloor subduction of tectonic plates precluded the formation of more than a nominal continental shelf at the coastline, and consequently made it considerably less likely that the region possessed exploitable hydrocarbon resources. Nevertheless this same seafloor configuration in concert with prevailing alongshore winds fostered coastal upwelling which nurtured a productive fishery that was integral to local economies; this fishery in turn served as fodder for the guano industry that had fueled South American economies for decades before modern technology achieved the process of nitrogen fixation and diminished the market for this avian-processed marine biomass. Intended to check incursions by long-range fishing fleets using modern, highly efficient equipment, the decision by the CEP countries to exert sovereign control over such an extensive region was dramatic, but certainly not without precedent: asserting control over the continental shelf generally does not extend near as far offshore as the CEP limit of jurisdiction – the continental shelf has an average width of 42 miles - but in promulgating this criterion the Truman Proclamation did so arbitrarily.[140]

Some degree of uniformity was necessary to clarify the multitude of contradictory claims of territorial and economic exclusivity made by the coastal nations of the world. To those and other ends, the United

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[138] Barkenbus, *Deep Seabed Resources*, 30; Hollick, "U.S. Oceans Policy: The Truman Proclamations," 24.
[139] Santiago Declaration of 1952 in Oda, *The International Law of Ocean Development: Basic Documents*, 345-6; Ross, *Opportunities and Uses of the Oceans*, 43.
[140] Frances Scott and Walter Scott, *Exploring Ocean Frontiers: A Background Book on Who Owns the Seas* (New York: Parent's Magazine Press, 1970), 99-102; Francis P. Shepard, *Submarine Geology* (New York: Harper and Brothers Publishers, 1948), 143. Shephard's seminal text on the ocean floor was published soon after World War II; of note on the flyleaf, "All of the latest data are presented, including much information gathered as a result of wartime research for the U.S. Navy."

Nations Law of the Sea Conference met in Geneva in 1958 to negotiate internationally acceptable limits to national maritime assertions, rights, and responsibilities. A draft set of laws to be considered as a basis for negotiating a universal and comprehensive Law of the Sea was drawn up over the course of years of effort from 1949 through 1956 by the International Law Commission (ILC), a body established by the United Nations Charter to codify existing international law and to "progressively develop" new areas of international law that might – theoretically - assist in governing the anarchical system of nations that emerged from the Second World War.[141] From this First United Nations Conference on the Law of the Sea held at Geneva in 1958 emerged four treaties that comprise the United Nations Conventions on the Law of the Sea I (UNCLOS I): the Convention on the Territorial Sea and the Contiguous Zone; the Convention on the High Seas; the Convention on Fishing and Conservation of Living Resources of the High Seas; and the Convention on the Continental Shelf.[142]

An ambitious effort by any standard, even so a number of the most contentious maritime governance issues that the international community endeavored to settle were approached only obliquely in the 1958 Conventions. One of these failures stands out: the inability to definitively establish the limit of the territorial sea was a concern for maritime powers and predestined the requirement for future negotiations.[143] The continental shelf was similarly treated with less rigor than was required to clearly delimit the extent over which nations enjoyed sovereignty with respect to the utilization and resources of its seabed and subsoil. The Convention on the Continental Shelf defined the region as "the seabed and subsoil of the submarine areas adjacent to the coast [and islands] but outside the area of the territorial sea, to a depth of 200 metres [sic] or, beyond that limit, to where the depth of the superjacent waters admits of the exploitation of the natural resources of the said areas."[144] The Convention's allowance for coastal State sovereignty over the continental shelf was more generous than what the Truman Proclamation had asserted a decade earlier for the United States. But unfortunately, the ambiguity that derived from the caveat on

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[141] Christopher C. Joyner, ed., *The United Nations and International Law* (Cambridge: Cambridge University Press, 1999), 6.
[142] The 1958 Geneva Conventions on the Law of the Sea in Oda, *The International Law of Ocean Development: Basic Documents*, 1-23.
[143] Clyde Sanger, *Ordering The Oceans* (London: Zed Books Limited, 1986), 10-20.
[144] 1958 Geneva Convention on the Continental Shelf in Oda, *The International Law of Ocean Development: Basic Documents*, 21.

exploitability left an equal amount of uncertainty over where the boundaries of national control were located. By the time of the Convention's entry into force in 1964, advancing technology proved to be the greater determinant of delimitation.[145]

Newly independent and economically disadvantaged states – a group that was expanding with the dissolution of colonial empires in the decades after World War II - looked upon a definition of the continental shelf based upon technical proficiency with apprehension. A legal regime that granted control of seabed resources to countries based upon their ability to realize exploitation progressively further down the continental slope (a dynamic definition that effectively shifted boundaries as technology improved) was far from equitable from their perspective. Developing country economies, based largely on the exploitation of natural resources as commodities, were threatened by the prospects of unfettered harvesting of competing ocean mineral resources by industrialized nations, the ultimate consumers. Keeping pace (or just catching up) with industrialized nations required overcoming enormous gaps in technology and capabilities. The countries that came collectively to be known as the Third World perceived one form of colonialism being replaced by another - a bitter taste made worse by an inability to compete, or at a minimum to participate.

Until a resource regime that offered more opportunity to participate could be realized, developing countries preferred stabilization to change.[146] But with marine technology advancing rapidly, the seaward extent of the continental shelf as established by the 1958 Convention was, in effect, a fluid boundary. Attempts to resolve the ambiguities regarding the definitions of the continental shelf and territorial sea were revisited at the Second United Nations Conference on the Law of the Sea in 1960, but this conference failed to produce consensus and the conventions of 1958 - as vague and ambiguous as they were - remained the ones pertinent to the field.[147] The resolution of this impasse was not to be found easily, especially since ambiguity favored the powerful industrial nations with the greatest capability to reap the benefits from the

[145] Malcolm E. Weiss, *One Sea, One Law?* (New York: Harcourt, Brace, Jovanovich, Publishers, 1982), 17.
[146] Eduardo Ferrero, "The Latin American Position on Legal Aspects of Maritime Jurisdiction and Oceanic Research," in *Freedom of Oceanic Research: A Study Conducted by the Center for Marine Affairs of the Scripps Institution of Oceanography University of California, San Diego*, ed. Warren S. Wooster (New York: Crane, Russak, & Company, Inc., 1973).
[147] Sanger, *Ordering The Oceans*, 18.

seafloor and the technology to exploit seabed resources steadily progressed ever deeper along the shelf from the coastline, muddying the waters even more. Instead, the catalyst for serious negotiation appeared because of a radical development that viewed this seaward boundary question from the *other* direction – one that took place in the deepest part of the oceans that remained well beyond territorial claim and was consequently focused upon that same boundary as a *shoreward* limit of exploitation. Once more the technologies developed to explore the oceans in support of undersea warfare made the difference, and again the United States found itself unintentionally and reluctantly instigating the greatest sea change in maritime law in history.

Much Ado About Nodules

From 1871 to 1876, Her Britannic Majesty's Ship *Challenger* sailed the Atlantic, Pacific and Indian Oceans on a dedicated oceanographic research cruise to study weather, ocean currents, marine life, and the physical properties of seawater and the ocean floor. *Challenger* was a British warship reconfigured to include laboratory facilities for a team of scientists led by naturalist Sir John Murray. Tasked exclusively with the study of the oceans, the *Challenger* Expedition completed almost 69,000 survey miles under sail and scientists catalogued thousands of new species in the three and one-half years of its voyage.[148] Collecting seafloor samples was a laborious process - obtaining a single bottom sample by dropping a weight with tallow or other sticky substance smeared to its surface or by a crude bucket dredge was a task that could take an entire day. It was from one of these samplings that scientists aboard *Challenger* catalogued the first recovery of dark, lumpy ferrometallic rocks from the deep seabed. The scientists recognized that these rocks, high in manganese content, had potential economic value (manganese was used in making steel), but they lacked the ability to recognize trace elements in the samples that would

[148] Tony Rice, *British Oceanographic Vessels 1800-1950* (London: The Ray Society, 1986), 30-39. From January through October 1991, *USNS H. H. Hess* conducted over 100,000 nautical miles of hydrographic surveys in the Pacific, Atlantic, and Arctic Oceans and Caribbean Sea. The author was the executive officer of the oceanographic unit.

eventually lead to even greater potential as a resource, and they estimated that the depth and difficulty of recovery of the nodules precluded economic exploitation.[149]

Challenger's scientific team did not fail to recognize the immediate financial benefit of other mineral discoveries of the cruise. Naturalist Murray and the British Crown grew rich from royalties derived from a phosphorite-mining venture established on Christmas Island.[150] Consequently, manganese nodules remained of limited scientific interest other than arousing some curiosity over the nature of their formation (manganese oxide was deposited in concentric layers around a hard central nucleus of rock, shark's teeth, or the ear bones of whales). The relative insignificance of the nodule find to the *Challenger* scientists is understandable – the expedition collected enough data to occupy researchers for twenty years and that eventually filled fifty substantial scientific volumes.[151] But interest in manganese nodules did not completely wither. When valuable trace elements present in the nodules were identified and quantified, the small black manganese nodules became objects of intense interest, albeit almost a century later.

As part of the investigations conducted during the International Geophysical Year (1957-58), a concerted international research effort by 8,000 scientists from 66 nations, large fields of manganese nodules were explored on the seafloor with the use of newly developed deep-sea cameras.[152] After studying the nodules on a subsequent research cruise, geologist Dr. John Mero of the Scripps Institution of Oceanography's Institute of Marine Resources decided their economic value had been vastly underestimated. Oceanographic inquiry of the ocean floor had exploded after World War II; a great deal of information was required about the characteristics of the sea bottom to determine material effects on the propagation of sound. In some cases sound penetrated the ooze and continued to propagate, in some it was

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[149] Broad, *The Universe Below*, 36, 255-256; Richard Corfield, *The Silent Landscape: The Scientific Voyage of HMS Challenger* (Washington: The Joseph Henry Press, 2003), 51-55.
[150] Eric Linklater, *The Voyage of the Challenger* (Garden City: Doubleday & Company, Inc., 1972), 279; Eugen Seibold and Wolfgang Berger, *The Sea Floor* (New York: Springer-Verlag, 1982), 236.
[151] Linklater, *The Voyage of the Challenger*, 278-279.
[152] Esso Educational Resources Division, *The Story of IGY: International Geophysical Year and the Earth Satellites* (New York: Esso Standard Oil Company, 1958), 22; Paul M. Fye, Arthur E. Maxwell, Kenneth O. Emery, and Bostwick H. Ketchum, "Ocean Science and Marine Resources," in *Uses of the Seas*, ed. Edmund A. Gullion (Englewood Cliffs: Prentice-Hall, Inc., 1968), 36; Walter Sullivan, *Assault on the Unknown: The International Geophysical Year* (New York: McGraw-Hill Book Company, Inc., 1961), 373; Edward Wenk, *The Politics of the Ocean* (Seattle: University of Washington Press, 1972), 216.

reflected, and in still others it was scattered haphazardly by uneven or rocky surfaces. Seafloor research received support it might never have realized had not it served to inform this aspect of security requirements. Research cruises early in the decade “rediscovered” the nodules on the floor of the Pacific. Interested in their potential, Mero had advocated investigating the possibilities of economic exploitation of manganese nodules as early as 1952, and his research results after the IGY convinced him of the “technical and economic feasibility of using [manganese nodules] as a source of various metals.” He identified minerals that the *Challenger* scientists were not able to detect, minerals such as cobalt, nickel, and copper that held economic importance. The scientist’s conclusions in the Institute of Marine Resources’ 1959 report, *The Mining and Processing of Deep-Sea Manganese Nodules* and his subsequent book published in 1965, *The Mineral Resources of the Sea* quickly drew interest from the commercial sector. [153]

Highlighting some of the advantages of exploiting manganese nodules from the deep seabed, Mero advocated the availability of mineral resources that did not require the removal of overburden or permanent on-scene infrastructure and support facilities, and that were located in a climate benign compared to the ones mineral prospectors were familiar with on land. He argued that advancing technology made it economically feasible to recover valuable minerals through deep seabed mining. What is more, he portrayed the nodules as a *replenishing* resource; this was somewhat of an overreach - in the aggregate total tonnage increased annually – but at an infinitesimal rate compounded only by the sheer volume of nodules.[154] Buoyed by Mero’s estimates of monetary return on investment, commercial interest was piqued and minerals consortia invested in mining and processing technologies and conducted resource surveys to locate the largest and richest nodule fields. Perhaps the most enticing aspect of all, surveys indicated the deposits were located primarily in the high seas, outside even extended resource claims of national ownership that had arisen since the Truman Proclamation and been ratified in the Geneva Conventions of 1958. But outside the sovereign control of any one nation, there was no guarantee that after a great deal of investment the integrity of an ocean claim could be maintained against foreign competitors. The capital investment and technical challenge was clearly substantial, and minerals markets were volatile. With profit

[153] Bartlett, ed., *The Ocean Environment*, 114; John L. Mero, *The Mineral Resources of the Sea* (New York: Elsevier Publishing Company, 1965), vi-viii; Seibold and Berger, *The Sea Floor*, 236.
[154] Mero, *The Mineral Resources of the Sea*, 242-72.

margin at stake, mining companies wanted assurances that they would not be interfered with once they made these large investments and were actively mining the deep seabed of the high seas.[155]

Manganese nodules are found in all oceans and some lakes. Some nodules are found in bottom sediments, but they are predominantly found on the surface of the ocean floor. Studies in the Southwest Pacific Ocean suggest that 20 to 50 percent of the ocean floor is covered with nodules representing some 2.35 million dollars per square kilometer (in 1981 dollars). A region with particularly rich nodule deposits between the equator and Hawaii covers an estimated 13 million square kilometers. [156] Manganese nodules are generally more abundant in the Pacific and Indian Oceans than the Atlantic, although exploitable densities are present in each of these basins. The nodules of the Atlantic are generally of lesser quality, with smaller percentages of valuable minerals. Samples of the estimated 1.5 trillion tons of Pacific seafloor nodules demonstrate concentrations of manganese, nickel, copper, and cobalt of 25, 1, 0.75, and 0.25 percent respectively. Their Atlantic counterparts display less rich proportions: 16, 0.42, 0.20, and 0.31 percent, by comparison.[157] Variations in nodule component concentrations vary with depth as well. Nodules from deeper locations show higher concentrations of manganese in relation to iron. Greater concentrations of lead and cobalt tend to be found in nodules formed in shallower seas, whereas copper and nickel show superior concentrations in nodules formed in deeper waters. Scientists still seek answers to why these concentrations vary, and why they demonstrate “millionfold” enrichments of minerals from available sea water source concentrations. This task is complicated by the geologic timescales of mineral deposition, with accretion rates that amount to atoms per year which equate to growth on the order of less than one millimeter per millennia.[158]

Manganese nodules vary in size, generally from 1 to 25 centimeters in diameter, but deposits also exist as crusts or even pavements in areas of bottom currents. Crusts of thicknesses up to 11 centimeters have

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[155] Wesley Marx, *The Frail Ocean* (Point Roberts: Hartley and Marks, 1999), 104-5.
[156] William A. Anikouchine and Richard W. Sternberg, *The World Ocean* (Englewood Cliffs: Prentice-Hall, Inc., 1981), 6; Barkenbus, *Deep Seabed Resources*, 3-11.
[157] Bartlett, ed., *The Ocean Environment*, 113; Fye, Maxwell, Emery, and Ketchum, "Ocean Science and Marine Resources," 36-38; F.L. La Que, "Deep-Ocean Mining: Prospects and Anticipated Short-Term Benefits," in *Pacem In Maribus*, ed. Elaine H. Burnell and Piers von Simson (Santa Barbara: The Center for the Study of Democratic Institutions, 1970), 19.
[158] Barkenbus, *Deep Seabed Resources*, 69-70; Seibold and Berger, *The Sea Floor*, 242.

been measured in the Eastern Pacific and continuous pavements averaging 7 centimeters thickness are found throughout the Blake Plateau, just off the coast of the Southeastern United States. Nodules are porous and rather easily crushed. They generally demonstrate a concentric structure with a hard central core, often of shark teeth or cetacean ear bones. Rates of accretion around the hard inner core had long been estimated on the order three to five millimeters per million years, but recent discoveries of anthropogenic articles with manganese accretion indicate that metal deposition may occur at faster rates under certain conditions in shallower water near the continents. The fact that manganese nodules - despite relatively slow rates of growth - are not buried by sediment raining down from above poses interesting questions regarding their development, and has led scientists to suggest that ocean floor currents, biological activity, or some other disturbances are responsible for keeping them at the surface. Some scientists suggest that progressive dissolution of the nodule base at the sediment interface, and subsequent redeposition on the upper surface, is a way of remaining above the sediment.[159] In whatever fashion they formed or succeeded in remaining unburied, what mattered to those interested in mining them was the fact that they were in plain sight – at least in plain sight of cameras suspended miles into the ocean – and ripe for harvesting.

Although the Truman Proclamation, pronouncements such as the Santiago Declaration, and the 1958 and 1960 Law of the Sea Conferences all attempted to delimit national prescriptive jurisdiction in the oceans, each did so with an eye to a seaward boundary that separated coastal state authority from the high seas. The high seas, however, had been largely treated since the time of Hugo Grotius and John Selden's debate in the 17th century in accord with the principle of *res nullius*, a doctrine that declared the seas and their bounty were not the exclusive property of any one entity. Grotius' concept of *mare liberum* asserted that no nation could harness the seas beyond a small acceptable territorial sea, while Selden's competing doctrine of *mare clausum* advocated the more expansive view that strong maritime nations (such as his native England at that time) were entitled to control areas of the open sea. The Grotian notion eventually

[159] Anikouchine and Sternberg, *The World Ocean*, 406-407; Bartlett, ed., *The Ocean Environment*, 114-116; Edward D. Goldberg, "Marine Manganese Minerals," in *Oceanography: The Last Frontier*, ed. Richard C. Vetter (New York: Basic Books, Inc., 1973), 67-81; Seibold and Berger, *The Sea Floor*, 239-243.

prevailed and the oceans beyond territorial seas (roughly defined by the three-mile cannon-shot rule) were treated as *res nullius*, the property of no nation.[160]

Fishing disputes had long brought nations to occasional blows (and contributed to the political climate behind the Grotius-Selden debate), but fish were predominately sought *above the continental shelves* in nutrient rich feeding grounds – and still are today. Even with the present depletion of fish stocks as a result of over fishing with modern gear, worldwide fisheries take increased dramatically from less than 20 million tons in 1950 to more than 130 million tons by 2002; the percentage of marine fish (as opposed to those taken in inland waters) remained at approximately 86 percent of the total catch throughout this period, and of these approximately 90 percent were neritic species endemic to waters above the continental shelf. Whereas the average width of the continental shelf is only 40 miles, it may be readily seen that nearshore regions encompass the probable flashpoints for most fishery disputes.[161] Nevertheless, despite the littoral precedent for economic exploitation – and possible resource conflicts involving parties with mutual claims to fisheries - the potential wealth of deep sea manganese nodules changed the focus on marine resources from one of "brown water" coastal resources to "blue water" seabed resources beneath the high seas.

The prospect of exploiting seabed minerals beyond the continental shelf raised questions over the legality of possession of fixed claims in the open ocean. Some level of proprietary control over the harvesting and husbandry of migratory fish stocks were accorded to fisherman that had long fished their bounty, even if the fish were far offshore or not exactly in traditional fishing grounds at some point of their life cycle. But the mineral resources of the deep sea were not migratory over time scales below geological

160 Grotius, "*Mare Liberum* (1608) Van Deman Magoffin Translation," 14-23; Robert Jay Wilder, *Listening to the Sea: The Politics of Improving Environmental Protection*, ed. Bert A. Rockman, Pitt Series in Policy and Institutional Studies (Pittsburgh: University of Pittsburgh Press, 1998), 3-28. Though it has been held widely that *Mare Liberum* is Grotius' definitive work on the nature of maritime law, some scholars contend that Grotius' later treatise, *De Jure Belli ac Pacis* provides a clearer notion of his concept for possession of maritime territory, one that does not imply freedom of the seas.
161 Jorge Csirke, *Review of the State of World Marine Fishery Resources* (Rome: Food and Agriculture Organization of the United Nations, 2005), 2; FAO Fisheries Department, *The State of World Fisheries and Aquaculture* (Rome: Food and Agriculture Organization of the United Nations, 2004), 10; "Governance of Exclusive Economic Zones," *Fisheries Global Information System*, 2005 (accessed April 20, 2005); available from http://www.fao.org/figis/topic?fid=12271.

– and even this realization did not come about until the same technologies that explored the seabed illuminated theories of continental drift in the 1960s! The capabilities required to harvest deep sea resources discriminated by means, in a similar way as the ability to project political power by naval force. Many nations had navies that plied their home waters, but relatively few had "blue water" fleets capable of extending their reach into the open ocean, an effort that required greater capital investment and technology (communications, submarine technology, underway replenishment, etc.) that left most nations in the shallows. As it did with respect to navies, the discrimination between a brown and blue water focus also represented a quantum distinction for resource exploitation; ultimately any competition to exploit manganese nodules appeared destined to discriminate by capability.[162]

One aspect of a regime subject to a doctrine of *res nullius* was that the lack of jurisdictional authority to prescribe restrictions left the wealth of the region vulnerable to those able to exploit it. Beyond national jurisdiction, the main limitations to harvesting the resources of the seas were technical. Extended range fishing had long been constrained more by processing and preservation than by the right of fishermen to harvest the species of the open seas. Similarly, oil and mineral exploitation had been limited by the depth of economic exploitation - a dynamic concept supported even in treaty law after the 1958 Convention on the Continental Shelf! But the capital investment that was required to exploit specific patches of the deep ocean floor brought an altogether new perspective to the unfettered-access versus exclusive-possession question on the sea bottom. It was not at all an ivory tower debate. At the July 1966 commissioning of the oceanographic research vessel *Oceanographer*, President Lyndon Johnson described the need for international cooperation in the oceans, "Under no circumstances…must we ever allow the prospects of rich harvests and mineral wealth to create a new form of colonial competition among maritime nations. We must be careful to avoid a race to grab and to hold the lands under the high seas. We must ensure that the deep seas and the ocean bottoms are, and remain, the legacy of all human beings."[163] If meant to forestall the enclosure of the high seas by exorbitant territorial claims or to hinder foreign efforts to mine manganese nodules to the detriment of US consortia; to protect U.S. naval interests from restrictions to freedom of

[162] Sanger, *Ordering The Oceans*, 126-128.
[163] Remarks of President Lyndon B. Johnson at the Commissioning of the Research Ship *Oceanographer* July 13, 1966 in Appendix 15 of Wenk, *The Politics of the Ocean*, 475-477.

movement; or to maintain the freedom to place instruments on the ocean floor (such as SOSUS arrays), President Johnson's comments unintentionally instigated something altogether different - an international reaction similar to that produced by the Truman Proclamation twenty years earlier.[164]

You Say Potato…The Genesis of the Law of the Sea

A speech delivered to the United Nations General Assembly in November 1967 by Arvid Pardo, the Ambassador of Malta, is widely held as the catalyst for the Third United Nations Law of the Sea Conference. Pardo's famous speech, in which he coined the phrase "common heritage of mankind" to describe the bounty of ocean resources that lay beyond national claims, was certainly the genesis in the United Nations General Assembly. But few recognize the intellectual debt Pardo owed Lyndon Johnson for catalyzing his own interest in the sea, and for describing the resources of the deep sea as the legacy of all human beings - even if Pardo's reinterpretation was slightly but significantly different than Johnson's assertion. The island of Malta received its independence from Great Britain in 1964, and Pardo's mission on behalf of the Maltese government was to develop the nascent nation's voice in the international forum of the United Nations. Pardo later recounted that Malta also hoped to land the headquarters of some UN Commission for both the recognition and the economic impact it would have on the tiny island nation. His early efforts to burnish Malta's Cross met with frustration and limited success. Ambassador Pardo then learned that the United States had requested the Secretary General to ask the United Nations Economic and Social Council to conduct a survey of the state of knowledge of seabed mineral resources and techniques for exploitation just months before Johnson's *Oceanographer* speech. At first he discounted the proposal as bureaucratic fluff, but "at a cocktail party…a member of the US delegation hinted that I should be careful [not] to criticize something I knew little about." Pardo threw himself into the study of all aspects of marine affairs and ocean resources, eventually becoming convinced that he had found Malta's niche: it

164 Marx, *The Frail Ocean*, 104-105.

would “play a useful role at the United Nations by seeking international acceptance of the concept that ocean space beyond national jurisdiction was a common heritage of mankind.”[165]

In his General Assembly speech Ambassador Pardo described the riches that lay on the deep-sea bottom, quoting spectacular estimates for the mineral wealth in manganese nodules in the Pacific Ocean from Mero’s *Mineral Resources of the Sea*, ignoring the geologist’s qualification that only a fraction might be *economically* recoverable.[166] Pardo suggested that the “forces that led to the national appropriation and intensifying exploitation of the continental shelf” would soon reach far beyond the shelf, aided by quickly advancing marine science and technology. He suggested “the known resources of the sea-bed and of the ocean floor are far greater than the resources known to exist on dry land…[and]…are also of vital and increasing importance.” Therefore, “Some countries may…be tempted to use their technical competence to achieve near-unbreakable world dominance through predominant control over the sea-bed and the ocean floor…[and]…impel countries with the requisite technical competence competitively to extend their jurisdiction over selected areas of the seafloor.” Pardo stated that current international law “encourages the appropriation of this vast area by those who have the technical competence to exploit it.” Though he most likely had the rapt attention of lesser-developed nations by this point, Ambassador Pardo subtly turned up the political heat when he obliquely identified the US request that the Secretary General conduct a survey of the ocean’s mineral wealth.[167]

Ambassador Pardo called for the creation of an international regime for the seas beyond “reasonably defined national jurisdiction” that would “face squarely the vital issues of legitimate national security together with economic, scientific, and other implications,” but suggested that such a body *not* be administered by the United Nations as it would be “hardly likely that those countries that have already

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[165] Arvid Pardo, "The Origins of the 1967 Malta Initiative," 1993 (accessed May 19, 2001); available from http://website.lineone.net/~romweb/par_a01.htm.

[166] "First Committee United Nations General Assembly, 1515th Meeting Official Records," in *First Committee*, United Nations General Assembly (New York: United Nations, 1967), 1-15; "First Committee United Nations General Assembly, 1516th Meeting Official Records," in *First Committee*, United Nations General Assembly (New York: United Nations, 1967), 1-2; Mero, *The Mineral Resources of the Sea*, 278; Sanger, *Ordering The Oceans*, 159-160.

[167] "First Committee 1515th Meeting," 1-15; "First Committee, 1516th Meeting," 1-2.

developed a technical capability to exploit the ocean floor would agree to an international regime if it were administered by a body where small countries, such as mine, had the same voting power as the United States or the Soviet Union." Pardo envisioned a trusteeship agency that would regulate exploration and exploitation of mineral, petroleum, and other resources, and suggested that the estimated five billion dollars in profit (following Mero's projections) from the exploitation of deep-sea minerals "be used to further either directly or through the United Nations Development Programme the development of poor countries." He called for a clear definition of the outer limits of the continental shelf that would effectively define the shoreward boundaries of such a deep-sea regime and for the establishment of "generally accepted principles with regard to the use of the deep seas and ocean floor." He appealed to a long-term fear of many nations when he invoked concern over the possible use of the seafloor by military powers for either nuclear or conventional weapons. Finally, Pardo called for a General Assembly Resolution proclaiming that the seabed and seafloor were the "common heritage of mankind" and were to be used and exploited only for peaceful purposes, with any profit realized to benefit all nations; that claims over the sea-bed and ocean floor "beyond present national jurisdiction" (a nod to Latin American countries)[168] be frozen until a clear definition of the continental shelf was agreed upon; that the UN establish an organization to consider all the ramifications of his suggested regime and draft a treaty that codified its principles; and for the establishment of an international agency that would ensure national activities on the seafloor conformed to those principles.[169] His statements stunned industrial nations and exhilarated underdeveloped nations. Arvid Pardo's suggestion implied that the wealth of the deep oceans was not just there for the taking; all nations, regardless of their ability to physically reap the resources should profit from what was a commonly owned and shared resource.[170]

Ambassador Pardo's speech was clearly a plea to the lesser developed nations to grab hold of what amounted to the last bit of unclaimed territory on the earth's surface before the industrialized nations appropriated it, even though they themselves were powerless to exploit its riches. It represented a

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168 Pardo, "The Origins of the 1967 Malta Initiative," (accessed).
169 "First Committee, 1516th Meeting," 1-2.
170 Barkenbus, *Deep Seabed Resources*, 32-33; Sanger, *Ordering The Oceans*, 18-19; Wenk, *The Politics of the Ocean*, 261.

philosophical shift away from the principle of *res nullius* towards *res communis*. Under such a regime attempts to exploit the seabed would not be Darwinian achievements by the "fittest" nations, but essentially reprehensible thefts of resources owned equally by others. The United Nations wasted little time in acting, possibly to focus its members on more positive pursuits in the wake of the Arab-Israeli Six-Day War earlier in the year that it had proved powerless to prevent.[171] Whether that was the rationale or because developing nations seized the opportunity presented them and decided to act, within six weeks of Arvid Pardo's speech the United Nations General Assembly established by Resolution 2340 (XXII) the *Ad Hoc* Committee to Study the Peaceful Uses of the Sea-Bed and Ocean Floor Beyond the Limits of National Jurisdiction and began the journey towards codifying a new Law of the Sea. The *Ad-Hoc* Committee, a 35-nation deliberative body chaired by Ceylon's Ambassador to the United Nations, H. Shirley Amerasinghe, was chartered to "examine activities of the United Nations and its agencies with respect to the seabed; relevant international agreements; scientific, technical, economic, legal, and other aspects of the question; and [make] suggestions on the promotion of international cooperation in exploration, conservation, and use of the seabed and its resources."[172] Pardo's gambit had succeeded. The United Nations, at the suggestion of Malta, "was now squarely involved in ocean affairs."[173]

At the end of 1968, General Assembly Resolution 2467 (XXIII) reframed the Ad Hoc Committee as the permanent Standing Committee on Peaceful Uses of the Sea-Bed and the Ocean Floor Beyond the Limits of National Jurisdiction (referred to generally as the Seabed Committee) with a broader mandate to study the legal principles, ways and means of promoting the exploitation and use of seabed resources, and to propose cooperative measures to prevent pollution of the marine environment from seabed activities.[174] The deliberations of the Seabed Committee led to the adoption of two resolutions in the General Assembly. Resolution 2749 (XXV), a Declaration of Principles Governing the Sea-Bed and the Ocean Floor, and the Subsoil Thereof, Beyond the Limits of National Jurisdiction was passed on December 17, 1970, by a vote

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[171] Sanger, *Ordering The Oceans*, 20.
[172] United Nations General Assembly Resolution 2340 (XXII) in Oda, *The International Law of Ocean Development: Basic Documents*, 33-34.
[173] Wenk, *The Politics of the Ocean*, 261.
[174] United Nations General Assembly Resolution 2467 (XXIII) in Oda, *The International Law of Ocean Development: Basic Documents*, 34-40.

of 108 to none with 14 abstentions. The Principles declared, “The sea-bed and ocean floor, and the subsoil thereof, beyond the limits of national jurisdiction (hereinafter referred to as the Area), as well as the resources of the Area, are the common heritage of mankind.” The Declaration further purported to forbid public or private interests from staking claims that would later prove in conflict with a regime established to determine access to and usage of the areas of the deep sea.[175]

UN General Assembly Resolution 2750 (XXV), issued that same day, reserved the Area described in Resolution 2749 “exclusively for peaceful purposes,” declared that its resources were to be used in the interests of mankind, and lastly proclaimed the decision to convene in 1973 a treaty conference on the Law of the Sea. The last mandate of Resolution 2750 was ambitious: to “deal with the establishment of an equitable regime – including an international machinery – for the area and the uses of the sea-bed and the ocean floor, and the subsoil thereof, beyond the limits of national jurisdiction, a precise definition of the area, and a broad range of issues including those concerning the regimes of the high seas, the continental shelf, the territorial sea (including the question of its breadth and the question of international straits) and contiguous zones, fishing and conservation of the living resources of the high seas (including the question of preferential rights of coastal States), the preservation of the marine environment (including, *inter alia*, the prevention of pollution), and scientific research.”[176] Seabed mineral exploitation had been elevated to a level of contention similar to fishing and navigation rights, petroleum exploitation, and growing apprehension over marine pollution - more established arenas of maritime (dis)agreement.[177]

Interestingly, marine scientific research - the catalyst for seabed mining issues, and integral to each of the other major concerns - was last on the list of negotiating objectives set forth in Resolution 2750. The General Assembly had in effect mandated a total renegotiation of the existing maritime order with significant new elements to deal with as well. What began as a research interest of marine scientists in the 1950s using the tools they inherited from an intensive effort to gain the upper hand in undersea warfare,

[175] United Nations General Assembly Resolution 2749 (XXV) in Ibid., 44-46.
[176] United Nations General Assembly Resolution 2750 (XXV) in Ibid., 46-48.
[177] Marx, *The Frail Ocean*, 105.

had morphed into the golden goose of economic development, and ultimately instigated an international effort to fashion a comprehensive agreement on maritime law that would first meet in New York in 1973, the Third United Nations Conference on the Law of the Sea.

With Mero's siren call, Johnson's steadying innuendo, and Pardo's radical twist to the issue, commercial interest in seabed mining expanded rapidly. Little was known about the successful prospects of harvesting manganese nodules from the deep seabed, but one thing was abundantly clear: the window of unregulated opportunity would not remain open indefinitely. Mining manganese nodules from the ocean depths had been likened, in various versions, to sucking peas or grains of sand through a soda straw from the top of the Empire State Building at night.[178] But the unknown offered as much opportunity as discouragement. Companies and consortia went to sea to survey the oceans for manganese nodule fields. Technology was developed to investigate finds and to determine the most effective means of exploiting them. Various methods of extraction were devised and patented. Some schemes used continuous line buckets; others employed suction pipes that scoured nodules from the seafloor and then injected compressed air at various levels along the length of the collection pipe to create bubbles that would expand as they rose and lift the nodules to the surface collection vessel. Research was applied to the processing of nodules to extract the minerals of interest with as little waste or danger to the environment as possible. Processing facilities were designed and built in prototype. Companies, consortia, and governments spent hundreds of millions of dollars in speculative research and development to determine how to harvest small black, potato sized nodules from the seafloor, process them into useable metals, and still make a profit.[179]

Even after the 1970 UN proclamation that declared the search for and exploitation of deep seabed minerals should cease until an international control regime was in place, the United States and other nations continued to allow companies to proceed with exploration and experimental mining and processing.[180] But a major change in the way that seabed mining was viewed did occur. Although the UN declaration did not strike the fear in the hearts and minds of the mining interests, it surely put the spectre of diminishing or

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[178] Ibid., 104.
[179] Barkenbus, *Deep Seabed Resources*, 3-25.
[180] Bartlett, ed., *The Ocean Environment*, 113-4, 125-6.

disappearing profits squarely in place. Outcry was long and loud throughout industrial nations over the uncertainty engendered by the UN declaration and prospective negotiations in the ensuing Law of the Sea Conference. Executives complained that venture capital would not invest in a scheme in which unfettered and exclusive access to resources discovered by the mining operations could not be guaranteed. They complained that some ill-defined international enterprise would reap the benefit of industry investment without the risk associated with development; that proposed production quotas to protect economies of countries dependent on land-based mineral exploitation would stifle profit margins, anathema to private industry. In the buildup to the Law of the Sea Conference, the Group of 77 lesser developed nations even expressed the desire for the international regime itself to function as a mining activity with technology transferred from the private consortia.[181] Although hundreds of millions of dollars had been poured into exploratory schemes, no one would proceed to the operational stages that industry projected would require over a billion dollar investment to build full-scale equipment and processing facilities ashore. Short-term success (before these proposals took hold) would not provide profit margins sufficient to amortize investment costs. Long-term stability would be required before the leap would be made, and that required international agreement over the "common heritage of mankind."[182]

Not all parties in the United States were put off by the turmoil caused by Ambassador Pardo's 1967 speech that reinterpreted President Johnson's words and proclaimed deep ocean resources to be the heritage of all mankind. The Department of Defense, inextricably involved in a worldwide game of maritime maneuver with the Soviet Union, saw light through the gloom of the deep seabed controversy. Many coastal nations, eschewing vestiges of colonialism after World War II, were becoming more assertive over their own sovereignty and rights within the international community. As described earlier, maritime territorial claims were expanding seaward. The old cannonball standard three-mile limit of territorial waters was in many places extended to twelve miles, not because cannonballs were any lighter but because of the ambiguity that the 1958 conventions added by means of contiguous zones. And upon review of a chart of the oceans, twelve-mile limits would restrict passage through many of what theretofore had been considered international straits and waterways.

[181] Ibid., 124. Marx, *The Frail Ocean*, 106.
[182] Barkenbus, *Deep Seabed Resources*, 28-42.

Although the right of innocent passage was largely recognized, many nations considered that a warship by its very nature did not fit this caveat. And this presented a problem to the United States Navy. Should the Soviet Union become allied with nations controlling strategic points of the world oceans, national security would be threatened. To avoid this scenario, the United States delegation to the United Nations supported international control of the deep seabed as incentive for developing nations to maintain an open and acceptable (to the United States) policy with respect to the waterways of the world.[183] Mining interests and their political champions questioned the pairing of the two issues. They protested that free passage through straits and coastal seas had long been established custom, a right of extended use that the U.S. Navy would not eschew in concession to vastly weaker states.[184] Connecting the issue of seabed mineral rights, an issue of (presumed) immense economic and to a certain degree strategic importance, to the freedom of navigation through waterways where it always existed only offered legitimacy to what should have been a negligible concern from a negotiation standpoint. But the link was forged, and it became one that could not be set asunder.

The United States later sought to modify its compromise concession in support of international control of the deep seabed to more of a traditional *res nullius* argument that the nodules were located in the high seas and therefore available to anyone that could recover them, a position that paradoxically satisfied no one… Industry felt this offered no long-term protection, and developing nations wanted international control. The issue would ultimately (ostensibly) lead to the refusal of the United States to sign on to the entire Law of the Sea Treaty. It is difficult to say how much collateral damage the United States suffered to its international reputation by its refusal to accept a treaty negotiated by over 150 nations through a long and arduous process that had significant U.S. investment. In the following years, the United States accepted de facto other provisions of the treaty. But the catalytic issue of deep seabed mining, an issue whose viability as a profitable economic enterprise was at all times questionable, prevented the United States from legally exploiting the deep seabed in any fashion. Not signing the treaty did not bind the

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[183] Marx, *The Frail Ocean*, 105.
[184] Marjorie Ann Browne, *The Law of the Sea Convention and U.S. Policy* (Washington: Congressional Research Service, 2003), IB95010.

United States to its norms, but it was difficult politically to selectively choose a la carte which of those norms it would follow when the treaty had such overwhelming international participation. Those provisions that the United States had historically practiced such as transiting international straits and innocent passage through territorial seas were much easier to justify on long-term use than ones involving issues only recently come to light because they were only recently made possible through the science and technology of post-World War II oceanography.

The United States had other opportunities to exert pressure during the Law of the Sea negotiations, possibly preserving rights to the deep seabed resources, yet it seemed determined to give up any negotiating advantage it had. When developing nations started the push for a 200-mile Economic Exclusive Zone in the early 1970s, the United States withheld its support as leverage over the seabed mining issue. Domestic pressure on the United States Congress from American fisherman to exclude foreign vessels from prime fishing grounds led to a unilateral declaration of a 200-mile exclusive fishing zone for the U.S. in 1976 via the Magnuson Fishery Conservation and Management Act. Leverage at the Law of the Sea negotiations evaporated.[185] The United States had also inadvertently heightened the fears of developing nations, who long suspected the U.S. was making a resources grab, when it fostered the notion that the Glomar Explorer, a ship it had developed to recover a sunken Soviet submarine, was part of a venture of Howard Hughes's Summa Corporation to mine nodules in the Pacific – despite the 1970 agreements to defer mining until the creation of an international governing body.[186] The diplomatic gaffes were not over.

United States negotiators then tried to argue that U.S. management of a seabed authority and unfettered access to ocean bottom resources would actually benefit all nations. Cheaper raw materials would lead to cheaper finished goods. U.S. credibility was only further undermined by this tack; developing nations perceived U.S. rationale as disingenuous.[187] In the end, the seabed compromise that eventually developed proved unacceptable to the United States. Caught between the leverage applied by domestic mining interests on elected government officials, and the international unity that coalesced around the U.S.'s own

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[185] Bartlett, ed., *The Ocean Environment*, 181; Marx, *The Frail Ocean*, 107.
[186] Barkenbus, *Deep Seabed Resources*, 18; Bartlett, ed., *The Ocean Environment*, 174; Broad, *The Universe Below*, 256-7.
[187] Barkenbus, *Deep Seabed Resources*, 54-6.

misguided maneuvers, the United States shocked the world by refusing to sign the Law of the Sea. Although the International Seabed Authority created by the UNCLOS III convention came into being, other than for brief periods to serve investigative purposes, no manganese nodules have been mined from the floors of the world's oceans, and no commercial profits have accrued to fill the coffers of the developing world.

One of the more frustrating aspects of this entire affair is whether deep-sea mining ever would have proved economically profitable - a question that lacked a sure answer during the years of speculative exploration that followed Mero's assertions in the late 1950s, throughout the ten years of negotiation over the 1982 UNCLOS III, and to some extent continues to the present day. Mero thought that the mining of manganese nodules always represented a profitable venture, and that apparent early disinterest from established shore-based mining companies merely demonstrated their desire to quell competition from new sea-based mining operations. He felt that (then) current dredge technology, married to techniques the oil industry developed to plumb the ocean depths, would easily suffice to harvest the nodules from the seabed. His estimates for the capital investment required in 1960 for an entire mining operation (removal technology, ore carriers, shore processing) totaled around $100 million dollars. When mining consortia eventually did become interested, studies were conducted and recovery and processing techniques innovated through active research and development. It quickly became obvious that figures would run much higher. In 1975 estimates ran five to six times Mero's estimates and by the 1982 Law of the Sea Convention, they were over a billion dollars (more recent estimates place the figure at almost two billion dollars).[188]

Balanced against investment, of course, is return. To be certain, there was a market for the minerals that were found in manganese nodules. Those present in the greatest percentages, manganese, cobalt, nickel, and copper, all had industrial utility. Copper was widely used in electrical applications (although speculation about glass fiber optic cable began to threaten the copper market in later analyses). Manganese, cobalt, and nickel were still valuable alloys in the production of steel, adding shock and

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[188] Ibid., 21; Broad, *The Universe Below*, 258-9.

abrasion resistance, heat resistance and stainless steel applications by their inclusion in the steel making process.[189] Estimates varied greatly on the profit margin associated with mining, but reached as high as $33 to $56 dollars per ton (before taxes), the variance caused by difficulty determining cost estimates for recovery and processing and a fluctuating metals market.[190] There was little doubt that the United States market for these metals was strong: by 1980 it was importing 100 percent of the manganese it used, and over 90 percent of cobalt and 80 to 90 percent of nickel requirements. The U.S. only imported 20 percent of its copper requirements but on a scale that exceeded import tonnage of the other three metals.[191] Not lost on the United States either, was the importance of these metals in building military vehicles, aircraft and weapons. This was of strategic significance considering the fact that its chief nemesis in the Cold War, the Soviet Union, was basically self-sufficient in these metals – not dependent as was the United States on potentially unstable Third World supplies.[192]

Ironically for those lesser developed nations that thought they would most benefit from a seabed mining scheme as envisioned in the 1982 Law of the Sea Convention, the economic impact of seabed mining competition on land-based suppliers could not be overlooked – for then-current supplies of the metals in question came overwhelmingly from developing nations and represented a large part of their gross national products. Most of the market effect was in copper, but cumulatively the metals represented over 95 percent of the exports of Zamibia, almost 92 percent of exports from Zaire, 78 percent of Chilean exports, 30 percent of Peru's export market, and varying lesser percentages of the export markets of over a dozen more developing nations.[193] Although profit margin would (and does) continue to be questioned with respect to deep-seabed mining, not all value can be read context-free from a balance sheet. Unless something changed with the metals market or somehow seabed mining became dramatically cheaper to undertake, the riches promised would (will) remain a pipe dream.

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[189] Barkenbus, *Deep Seabed Resources*, 5-6; Broad, *The Universe Below*, 255-6.
[190] Barkenbus, *Deep Seabed Resources*, 23.
[191] Ibid., 62; Bartlett, ed., *The Ocean Environment*, 116-7.
[192] Bartlett, ed., *The Ocean Environment*, 173-4; Broad, *The Universe Below*, 260-2; Gardner M. Brown and James A. Crutchfield, eds., *Economics of Ocean Resources* (Seattle: University of Washington Press, 1982), 79-80; Ross, *Opportunities and Uses of the Oceans*, 151-153.
[193] Barkenbus, *Deep Seabed Resources*, 52; Joseph M. Bishop, *Applied Oceanography* (New York: John Wiley and Sons, 1984), 184-5; Brown and Crutchfield, eds., *Economics of Ocean Resources*, 77; Seyom Brown, Nina W. Cornell, Larry L. Fabian, and Edith B. Weiss, *Regimes for the Ocean, Outer Space, and Weather* (Washington: The Brookings Institution, 1977), 79-84.

The story of seabed mining as the catalyst for the Third United Nations Convention on the Law of the Sea and the most comprehensive treaty ever with respect to maritime interests does not end with the failure to actively and economically exploit seabed minerals. In fact, the reasons stated by President Ronald Reagan when he rejected the treaty did not include the inability to exploit the resource economically. Instead, President Reagan and the United States rejected the interference with free market principles embedded in the International Seabed Authority regime including the imposition of production quotas as price controls and mandatory technology transfer; certain other provisions that endangered American interests such as "backdoor" alterations of the treaty that could be passed without the United States' consent; and the precedent that these provisions might set for other international agreements.[194] No specific naval objections were voiced; apparently the specific protections that would have been provided to the Navy were not novel enough or secure enough for security interests to trump economic and ideological ones in this instance.

The Cold War was not over, but the strategic situation had changed over the fifteen years since Arvid Pardo had set the chain of events in motion for UNCLOS III with his vision for the exploitation of manganese nodules and a regime to oversee the resources of the seabed. One of the concerns earlier in the days of ballistic missile deterrence was range, and although submarine launched missiles were important for the stealth and second-strike capability they possessed, they were of limited use if they could not be "hidden" within legitimate striking range. To some extent the ability to deploy submarines stealthily around the world depended upon getting them to patrol stations through chokepoints and coastal areas clandestinely – an ability that would have been threatened if the terms of the Law of the Sea were too tightly controlling. The United States Government and the Navy had to be concerned over this possibility and were therefore willing to tie the issue to one the United States could afford to use as trade bait: manganese nodule mining. By the time the treaty was ready for signature, the United States had progressed from the 1,000-mile plus range of the first *Polaris* missile through two more variants that increased range

[194] The President's Ocean Policy Statement, 10 March 1983 in George V. Galdorisi and Kevin R. Vienna, *Beyond the Law of the Sea: New Directions for U.S. Oceans Policy* (Westport: Praeger Publishers, 1997), 187-189.

and payload, to the *Poseidon* missile with greater than 2,000 nautical mile range and multiple independent reentry vehicle (MIRV) technology that mounted multiple warheads on a single missile. On the drawing board was the *Trident* missile that promised to double that range. The U.S. Navy's ballistic missile submarine force was deployed throughout the oceans with these long range missiles, and before the Walker Spy scandal and the Toshiba affair eroded it the Navy enjoyed the lopsided advantage it maintained in undersea warfare thanks to SOSUS, the SURTASS ships and shore processing facilities that it collectively grouped into the Integrated Undersea Surveillance System (IUSS). With power projection during the Cold war reliant so heavily upon strategic deterrence of Soviet ambitions, the strengthened position of the United States in this area allowed it flexibility to be more selective in what it supported in the Law of the Sea negotiations.

While it took almost every opportunity that it could throughout the Cold War to oppose the United States directly or through an enemy-of-my-enemy approach that supported the U.S. antagonist *du jour*, with respect to the Law of the Sea the Soviet Union found itself in the awkward negotiating position of worrying about many of the same constraints that the United States opposed apropos the mobility of its naval forces. Early in its history, the U.S.S.R. did not have much of a maritime presence – especially after the trouncing of the predecessor Czarist Fleet at Tsushima early in the century. The Bolsheviks did not inherit much of a Navy in 1917 after deposing the czar and once they withdrew from World War I had their plate full with shaping the domestic political system they had imposed into a proper Socialist state. After World War II, however, the Soviet Union began to assert its hard-won status as a world power and began to enforce its territorial seas from the incursion of foreign fishing - and other - fleets. At the same time it put to sea a large commercial fishing fleet to provide an alternative source of protein to its large population still struggling to reestablish itself after the devastation of World War II. In response to the United States position as an opponent in the Cold War, the Soviet Union expanded its naval presence dramatically to project power closer to the Americans who were otherwise still insulated by two broad protective oceans.

With enhanced naval interests, the U.S.S.R. also reconsidered its ardent defense of an extended territorial sea. "This growth of the Soviet Navy…contributed to the transition from the protective, security-

oriented maritime jurisprudence of the postwar era to a greater interest in the freedom of navigation on the high seas." [195] In just about every other conceivable instance an opponent, with respect to the negotiations for a universal Law of the Sea the Soviet Union shared American interests in maintaining unimpeded navigation and access in order to move its fleets where and when they needed in support of their global Cold War strategy. In the latter half of this confrontation, just as the United States became less constrained in its Law of the Sea concerns as its missile technology improved striking range, the same might have been said for the Soviet Union. But as many who witnessed the Soviet Navy up close will attest, it rarely did away with any weapon in its arsenal even as new ones were devised and installed – a tendency that made its ships bristle with deck-mounted armaments. The same might be said for its willingness to bend on issues of strategic advantage; right up to its demise the U.S.S.R. remained a non-signatory to the Law of the Sea treaty.[196]

Ten years after President Reagan declined to sign the 1982 United Nations Convention on the Law of the Sea, President William Clinton joined in the 1993 consultations initiated by the Secretary General of the United Nations in an attempt to generate support for the Law of the Sea Treaty that had yet to come into force. Once again the strategic situation had changed for the United States. Although it took a few years and some significant second-guessing over how the situation would fully resolve, the Cold War was over after a dramatic series of events in the Soviet Union at the end of the 1980s and in the early 1990s. Suddenly a "peace dividend" seemed a possibility - one that stretched beyond the economic dividend of money saved on defense spending, to a political one that allowed the United States to view the world through rose-colored glasses instead of the dark lenses of the Cold War days. President Clinton's foreign policy was one of economic engagement, and the benefits that might be enjoyed by participating in this multilateral treaty could be measured differently than in the days of "bean counting" in terms of strategic military advantage.

[195] William E. Butler, *The Soviet Union and the Law of the Sea* (Baltimore: The Johns Hopkins Press, 1971), 200-202.
[196] The Russian Federation signed and ratified the United Nations Convention on the Law of the Sea in 1997.

An Agreement for the Implementation of Part XI of the United Nations Convention on the Law of the Sea was crafted during the Secretary General's consultations. The President felt that the agreement resolved most of the professed objections to the seabed mining and International Seabed Authority provisions of the convention. It should not be overlooked at this point that some domestic political posturing was in play in an election year that determined control of the United States Senate, the body who's Committee on Foreign Relations was first required to vet the treaty before passing it on to the entire Senate for its advice and consent on ratification. President Reagan's ideological stand required consistent defense by the Republican Party while Democratic President Clinton's actions forced considerable assessment of the political capital at stake by ratifying or not ratifying the Law of the Sea Treaty. The President submitted both the Convention and Agreement to the Senate in October 1994 where it was referred to the Senate Committee on Foreign Relations. The Senate took no action to ratify the treaty (with elections only days away), and the Law of the Sea Convention entered into force without accession by the United States in November 1994. The Agreement from the Secretary General's consultations entered into force in July 1996, again without accession by the United States.[197]

"Every succeeding scientific discovery makes greater nonsense of old-times conceptions of sovereignty."

--- Sir Anthony Eden[198]

The relationship between science and security is one of strained symbiotic interdependence. Academic scientists pride their profession's open exchange of information and (ideally) apolitical view of the world, focusing on the advancement and dissemination of knowledge above the short term vicissitudes of national or international affairs. Security specialists on the other hand, tend to view the ivory tower of academic science as perhaps a little out of touch with reality. When the two fields meet they tend not to amalgamate into an alloy, but rather to join for the time being or the task at hand – ever ready to release ties and let the other return to their myopia when the impetus to work together has waned. This is certainly the case with respect to oceanography and security concerns; when joined they realized some spectacular achievements: quantum scientific advancements of knowledge about the ocean environment, and possibly the only

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[197] Marjorie Ann Browne, *The Law of the Sea Convention and U.S. Policy* (Washington: Congressional Research Service, 1998), 1-2.

[198] Sir Anthony Eden, "Sovereignty," (accessed April 13, 2005); available from http://www.sbrowning.com/quotes/index.php.

tactically effective methodologies to wage undersea warfare. Both however paid a price for this on-again, off-again partnership as each became subject to changes that took place in the other's realm. This current study reflects mostly on how those changes in the understanding of the ocean environment that grew from the need to apply ocean science to security challenges went on to affect security in unanticipated ways. But this was not a one-way proposition. As a science, oceanography gained significant traction as a result of its function as a "force multiplier" – applied oceanography made military operations more effective than they would have been without the benefit of its assistance. In return, the patronage of security coffers established the science at a big science level, providing some constant measure of financial support, but also making possible spectacular advances that reached into areas where funding streams might be tapped independent of the security spigot. Shifts in congressionally mandated allocation of research funding also helped remove some of the "taint" associated with military-sponsored research when the National Science Foundations assumed a greater responsibility for funding basic oceanography in the 1960s and 1970s. Still, oceanography would not easily out the spot security interests etched on its fabric.

In the ideal, "pure science" exists beyond the reproach of ulterior motive, and oceanography became tainted by its association with security. Although that relationship meant a more permanent patronage for ocean research, it also meant that an inherent distrust for some of its endeavors was engendered in observers – especially those with jurisdiction over coastal areas that scientists wished to investigate. Knowledge is intrinsically a double edged sword that might serve two very different purposes by the manner in which it is wielded; for ocean science both edges are simultaneously annealed in sea water in almost every way and for whatever motive that oceanographic investigations are undertaken. The successes oceanography enjoyed through its applications to naval warfare and as a result of the valuable resources it exposed in the deep were also its failings, and ocean scientists that sought to explore the secrets of the sea became in a sense victims of this success. Never again would the science be viewed only as the pursuit of "knowledge for the greater good" – an aura that it had enjoyed in its earliest days. This is important in ways even yet to be realized, for future efforts in oceanography with their untold implications for science and for security will be undertaken under this cloud of suspicion – a cloud that formed in the

turbulent days of Cold War oceanography and that lingers high above it even in the post-Cold War world.[199]

"All States, irrespective of their geographical location, and competent international organizations have the right to conduct marine scientific research…." Part XIII: Marine Scientific Research of the 1982 United Nations Law of the Sea Convention (UNCLOS III) begins auspiciously enough. However, marine scientists in the United States and other developed nations with oceanographic interests largely view the provisions of the international regime described by Part XIII with trepidation. Triskaidekaphobia aside, they perceive a bureaucratic threat to effective scientific research in the oceans.[200] The 28 articles that comprise Part XIII, together with the numerous references to marine scientific research in other articles of UNCLOS III, describe a regime of open access for scientific inquiry on the high seas, but that defers to coastal nation sovereignty in territorial waters and exclusive economic zones that extend seaward up to 200 miles (even further in certain cases with respect to the seabed and subsoil of the continental shelf) from the baselines that demarcate landmasses and internal waters from territorial seas. Within this province - a region that largely circumscribes the biologically active and geophysically variable (hence, the most scientifically intriguing) neritic zone that stretches from the shoreline to a water depth of 200 meters and encompasses some 40 percent of the oceans - scientific research may be conducted only with a coastal nation's negotiated consent and the research nation's compliance with certain other international considerations.[201]

Oceanography, eventually subsumed into "marine scientific research" when it entered the international legal lexicon, in its own right and as it facilitated the exploitation of the seabed became the catalyst for negotiations that sought to resolve ocean resource dilemmas along with a plethora of traditionally contentious maritime issues by realizing a universal Law of the Sea. It was a process that began with the close relationship between oceanography and security in World War II, was addressed with the first efforts

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[199] Unfortunately this cloud provides no benefit to offset the loss of stratospheric ozone…
[200] Warren S. Wooster, ed., *Freedom of Oceanic Research: A Study Conducted by the Center for Marine Affairs of the Scripps Institution of Oceanography University of California, San Diego* (New York: Crane, Russak, & Company, Inc., 1973), 1-4.
[201] David A. Ross and John A. Knauss, "How the Law of the Sea Treaty Will Affect U.S. Marine Science," *Science* 217, no. 4564 (1982).

to devise the Law of the Sea, and reached its schizophrenic simultaneous encouragement and constraint of the science in Part XIII: Marine Scientific Research of UNCLOS III.

Little specific mention of marine scientific research is made in any of the 1958 Geneva Conventions. The subject is interwoven throughout the Fisheries Convention as a matter of understanding the health, abundance, and conservation of fish stocks, but in no delimiting fashion. Marine scientific research is not mentioned at all in the Convention on the High Seas, and is most notably absent from the Convention's four specified freedoms: navigation, fishing, the laying of submarine cables and pipelines, and the freedom to fly over the high seas. The High Seas Convention relegates scientific research to the subjective interpretation of "others [freedoms] which are recognized by the general principles of international law…to be exercised with reasonable regard to the interests of other States in their exercise of the freedom of the high seas."[202] The obvious uncertainty over the width of the territorial sea made vague where clearance might be required to conduct research in water within twelve miles of the coastline. The International Law Commission, in formulating draft articles for the 1958 Geneva Conference, made specific mention of scientific research in its commentary with respect to freedoms of the high seas (acknowledging that research was considered a high seas freedom), but decided to omit the issue from the four freedoms it elicited because marine exploration and the exploitation associated with research "had not yet assumed practical importance to justify special regulation."[203] Yet!

Of the four 1958 agreements, the Convention on the Continental Shelf was the most influenced by - and had the most impact upon - marine scientific research. Oceanographic research on the continental shelf was made subject to coastal state notification *and consent* for "research concerning the continental shelf and undertaken there." Article 5(1) of the Convention implied some level of preference for scientific research: exploration of the shelf and the exploitation of its resources by a State (or presumably entities authorized by the State) were not to interfere with the conduct of scientific investigations when

[202] 1958 Geneva Convention on the High Seas in Oda, *The International Law of Ocean Development: Basic Documents*, 9.
[203] International Law Commission, "*Document A/3159:* Report of the International Law Commission covering the work of its eighth session, 23 April - 4 July, 1956," in *Yearbook of the International Law Commission 1956* (New York: United Nations, 1956), 278.

"fundamental oceanographic or other scientific research" was "carried out with the intention of open publication." In the same vein, Article 5(8) stated that coastal state consent would not be "normally withheld" if the request came from a "qualified institution" intending to conduct "purely scientific research into the physical or biological characteristics of the continental shelf" with the intent to publish results.[204] Though positive statements for science, the way was not clear. The articles made no attempt to clarify what constituted a "qualified" institution or "fundamental oceanographic or other scientific" (or for that matter "pure") research. The relationship and utility of marine scientific research to naval applications and to economic exploitation grayed the definitions of what might be considered "fundamental" or "purely scientific" research, uncertainty that worked in favor of States seeking to deny authorization to perform research off their coastlines.

Coastal states concerned that either a security or economic motive was the impetus for the research would be disinclined to allow it, on sufficiently justifiable argument. In any case, states that recognized the military and economic implications of research would, in all probability, refuse the "open publication" of such information. Equally irresolute was the extent of coastal state jurisdiction over research on the continental shelf beneath the high seas: did actual physical contact with the continental shelf have to take place for research to be subject to coastal state consent regime, or did the intent of the language possibly include investigations in the adjacent water column? The Convention on the Continental Shelf (in Articles 1 through 3) distinguished the shelf from the water column in prescribing state jurisdiction over shelf resources, but acknowledging high seas freedoms in the superadjacent waters not a part of territorial seas.[205] However, the increasing ability of scientific instruments to acoustically sample properties of the ocean bottom and subfloor without physical contact made this much more than a semantic argument. Most of the ambiguities favored coastal state prerogative. Although far from universally recognized or applied by coastal nations, the articles of the 1958 Convention on the Continental Shelf prescribed the first deliberate international restrictions on marine scientific research.

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[204] 1958 Geneva Convention on the Continental Shelf in Oda, *The International Law of Ocean Development: Basic Documents*, 21-22.
[205] Ibid., 20-21.

The fact that marine scientific research rated mention (and restriction) in the 1958 Geneva Conventions implies that nations were coming to understand a connection between marine research and exploitation - economic or military - in waters near their shores that they might desire to hinder or prohibit. To this point, marine scientists had felt they enjoyed a longstanding immunity from strict adherence to territorial boundaries or exclusive zones. They were not without a basis in making these assumptions; historically marine scientific research received special consideration when legal scholars made mention of its status. As one of the Restrictions on the Right of Capture of Enemy Property, C.J. Colombos (a British author writing before the 1958 Conventions were in force) referred separately to Ships Engaged in Scientific, Religious or Philanthropic Missions. Colombos argued that international practice prior to the 1958 Conventions "in accordance with a rule of long-standing recognition" accorded these ships immunity from seizure. He indicated that scientific vessels were furnished passports, a practice insularly (if not haughtily) described as having been "initiated at a time when communications with regions outside the civilized world were very difficult."[206]

Colombos noted that the 4th Article of the Eleventh Hague Convention of 1907 formalized this practice, "Vessels charged with religious, scientific, or philanthropic missions are likewise exempted from capture," subject to the same provisos for vessels offered similar immunities: they maintained these special privileges only through "abstention from all interference in hostilities."[207] In elaborating the protections afforded scientific missions, Colombos asserted that privileges were accorded because of the nature, rather than the sponsor, of the mission: "…immunity from capture is not confined to public missions, but applies also to private undertakings." Protections conferred on scientific missions according to this view - again, which he considered traditional practice - did not hinge on whether the undertakings were the efforts of governments, but included those of private institutions and individuals. Colombos contended that it was acknowledged

[206] C. John Colombos, *The International Law of the Sea*, 5th ed. (London: Longmans, Green and Co Ltd, 1962), 564-565.
[207] Ibid., 565; "Convention (XI) Relative to Certain Restrictions With Regard to the Exercise of the Right of Capture in Naval War (1907)," 2001 (accessed April 17, 2001); available from http://fletcher.tufts.edu/multi/texts/BH043.txt.

that an expedition had to furnish the coastal government full information about the nature of its mission before guarantee of safe passage was granted.[208]

Addressing Neutrality in Naval Warfare, Colombos again acknowledged the separate nature of scientific missions, referencing the norms of the Thirteenth Hague Convention of 1907. The 12th article of this convention required, when war was declared, that belligerent warships vacate neutral ports, roadsteads, and territorial seas within 24 hours. However, an exception to this rule was accorded in Article 14, permitting extended stay for "warships entering a neutral port in distress or owing to stress of weather or which are exclusively devoted to religious, scientific, or philanthropic missions."[209] Not all nations ratified or acceded to the Thirteenth Hague Convention; Colombos noted that Great Britain decided the Convention was not in its best interests, for "while in the main embodying rules of general acceptance, [it] contains several articles which the British delegation reserved on signing."[210] But Britain's objections were not over the status of scientific missions. Colombos' contemporary, H.A. Smith, attributed the failure of Great Britain to ratify the Thirteenth Hague Convention to objections over two articles that addressed the provisioning of warships and the issue of prizes in neutral ports. Writing just after the 1958 Conventions were negotiated, Smith asserted that the Thirteenth Hague Convention, notwithstanding the British objections noted "accurately stated the position of general agreement"[211] and gave "a fair summary of the law of neutrality as developed in the course of the previous century."[212] According to both scholars, marine science had historically been afforded special status that provided certain immunities and freedoms for scientific missions in areas that would otherwise have been unavailable to ships flying the same flag but conducting different missions.[213]

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[208] Colombos, *The International Law of the Sea*, 565.
[209] Ibid., 610-611; "Convention (XIII) Concerning the Rights and Duties of Neutral Powers in Naval War," 2001 (accessed April 17, 2001); available from http://fletcher.tufts.edu/multi/texts/BH044.txt.
[210] Colombos, *The International Law of the Sea*, 364-5.
[211] H. A. Smith, *The Law and Custom of the Sea*, ed. George W. Keeton and Georg Schwarzenberger, Third ed., The Library of World Affairs (New York: Frederick A. Praeger, *Publishers*, 1959), 91.
[212] Ibid., 180.
[213] The United States recognized a difference between some combatant and non-combatant vessels under foreign flag as of 1898, if not earlier in some instances. The U.S. Supreme Court decided in the case of the *Paquete Habana* and the *Lola* that fishing vessels, sailing under an enemy's flag but innocently pursuing the "peaceful calling of catching and bringing in fish" were exempt from capture as prizes of war. United

Where the International Law Commission's statement in its commentary to the draft articles submitted to the First Law of the Sea Conference regarding the practical importance -or more appropriately, lack thereof - of marine science to issues requiring agreements of international law was *somewhat* correct in 1956, the momentum that ocean sciences had achieved during WWII and carried into the 1950s and 1960s steadily overcame this conclusion. Many Law of the Sea issues considered by the ILC prior to Geneva were "traditional," and those issues that had emerged or were facilitated through marine science such as the discovery and exploitation of non-living seabed resources were not seen as concerns in relation to their physical revelation as much as they were for their political significance. But these discoveries and progress in marine science and technology *were* likely the not-blatantly-obvious-but-increasingly-evident root of differences that contributed to the political inability to resolve boundary ambiguities of territorial seas and continental shelves at the First United Nations Law of the Sea Conference. Their impact was no more obvious at the second Law of the Sea Conference two years later, but public consciousness of marine science was still at an early stage. Ultimately though, advances in marine science and technology moved beyond the limits of the continental shelf, and presented the opportunity to harvest previously unreachable resources of the deep sea floor. The projected impact of such a proposition elevated the status of non-living marine resources to national and international attention. When the international community met once more to resolve the questions surrounding the exploitation of such wealth, marine science was recognized as integral to the issue. But this was still some years in the distance.

The Second United Nations Law of the Sea Conference met in Geneva in 1960 to deal with shortcomings of UNCLOS I. It failed. A compromise effort to define the limit of territorial seas did not pass, perpetuating the uncertainty of the extent and validity of national claims.[214] Mariners remained subjected to an ocean-going version of Russian Roulette. Fishermen who thought they were fishing international waters - and were as far as their flag states were concerned - found themselves in trouble off the coast of South America where countries exerted seaward claims of over 200 miles after the Santiago

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States Supreme Court, 1900., 175 U.S. 677, 20 S.Ct. 290, 44 L.Ed. 320 in Joseph Modeste Sweeney, Covey T. Oliver, and Noyes E. Leech, *Cases and Materials on The International Legal System*, ed. David L. Shapiro, Third ed., University Casebook Series (Westbury: The Foundation Press, Inc., 1988), 4-11.

[214] Sanger, *Ordering The Oceans*, 18.

Declaration.[215] In 1969 the Peruvian Navy seized 14 vessels of the United States' long-range tuna fleet; one boat suffered considerable damage from machine-gun fire. The vessels would have been allowed access to the disputed fishing grounds had they paid extensive license fees, but diplomatically this was unacceptable as it would have acknowledged and implied acceptance by the United States of the extended CEP claims. Adding insult to injury, seizures made by Ecuadorian authorities were made by craft the United States had loaned to Ecuador. The United States did not offer protections to the fishing vessels, but also did not prevent their incursion into contested waters. Eventually the United States Congress passed legislation that provided reimbursement to fishermen for their losses with federal funds that were offset by equivalent reductions in foreign aid to the nations that conducted the seizures.[216]

The 1958 Convention on the High Seas and the Convention on the Continental Shelf - ratification of or adherence aside - had focused attention on the issue of limiting foreign access to those areas under a coastal state's control, as ambiguously defined as they were. Even if the economic exploitation of coastal resources by foreign states was limited or virtually non-existent, States desired to restrict incursions by vessels into these waters without their positive consent in order to obviate precedents. Nations that wished to conduct scientific research off the coasts of foreign states, primarily maritime powers like the United States and the Soviet Union that could afford the high cost of research fleets, consequently found themselves increasingly restricted in these areas of disputed authority. The previously dormant issue of clearances had been aroused. Where in the past country clearances were but a formality, if necessary at all, they were at this juncture potentially showstoppers. There were no guarantees that clearances would be given to research vessels, and if they were, when. The capability to reasonably plan voyages in advance, or to avail of the freedom to adjust survey plans to plumb the earlier discoveries of a voyage evaporated to a large extent with the seaward extension of territorial claims. The irony of the situation was such that even if a coastal state was generally willing to grant clearance or change requests, scientists were equally subject to the vagaries of their home nations' discretions. Some requests moved no further than domestic bureaucratic channels unwilling to forward the paperwork - applying for clearance implied

[215] Ross, *Opportunities and Uses of the Oceans*, 47-54; Scott and Scott, *Exploring Ocean Frontiers: A Background Book on Who Owns the Seas*, 100-101.
[216] Scott and Scott, *Exploring Ocean Frontiers: A Background Book on Who Owns the Seas*, 100-101.

acknowledgement of jurisdiction (similar to the license fee issue in CEP waters), a Catch-22 that was as capable as the denial of a clearance request by the coastal state to trip up scientific effort to conduct investigations in littoral regions.

Marine science was in some ways its own worst enemy. The traditional freedoms it enjoyed may not have existed long in the post-war international order, but had marine science "remained below the radar" it might not have become an issue of contention to be specifically negotiated and regulated in the Law of the Sea. It was still an emerging discipline after World War II, endeavoring to identify its specific niche and rectify its multidisciplinary nature with the focused character of traditional sciences and develop rigorous curricula in university environments. Marine science entered the wider public consciousness in the 1950s with the publication of Rachel Carson's ocean trilogy *The Sea Around Us* (1951), *Under the Sea-Wind* (1941, reprinted in 1952 after the success of *The Sea Around Us* made Carson marketable) and *The Edge of the Sea* (1955), and in the 1960s through the films, books, and television shows of Jacques Cousteau and a television series featuring a dolphin named *Flipper*. The effective military use of oceanography in its many facets during World War II may not have been broadly understood and appreciated by the public (and successes of the Cold War became largely public only years later), but scientists and military strategists were aware of the role that it played and continued to play throughout the Cold War. The prominent tragedy of the *Thresher* and the subsequent efforts by the Navy to mollify the American public (and submariners!) with pledged emphasis on undersea capabilities and deep submergence rescue - followed soon after by the spectacular retrieval of the hydrogen bomb off Palomares - further elevated the nascent science to the attention of policy makers. In addition to an emerging awareness of the connection and growing importance of oceanography for military applications, the steady march in marine resource exploration and ever deeper exploitation by the petroleum industry after World War II provided valid reasons for coastal states to look warily upon requests to conduct research off their shores.

The 1958 Geneva Conventions had first raised marine science as a facet of the international order to be regulated rather than freely fostered, but not through patent restraints. Instead, UNCLOS I initiated some

level of attention and control over marine scientific research incidental to more traditional Law of the Sea issues. It bore relation to freedoms on the high seas (marine scientific research was understood to be such a freedom, according to ILC commentary) and as an issue whose exercise was subject to jurisdictional boundaries with respect to resource prospecting on the continental shelf; but marine science was not treated as a separate element of concern for coastal states. The ambiguity of references to it (and lack thereof) in those cases, however, resulted in a certain amount of confusion for its practitioners over the conduct off the coasts of foreign nations. Eventually, one of the express goals of UNCLOS III would be to remove ambiguity and determine a definite framework for the pursuit of marine scientific research in waters under a foreign nation's jurisdiction. But that clarity was still a way off.

From the first inklings of outside interference with "how things were done" that developed with the 1958 Conventions, through the growing unease of the 1960s when countries began to assert their jurisdiction over their coastal regions in earnest, to the placement of marine scientific research on the international agenda by Resolution 2750 (XXV) of the United Nations General Assembly, oceanographers stirred in defense of their science. Through their national delegations to the Seabed Committee and through international organizations such as the International Council of Scientific Unions' (ICSU) Scientific Committee on Oceanographic Research (SCOR), the International Council for the Exploration of the Sea (ICES), and the Intergovernmental Oceanographic Commission (IOC), scientists attempted to develop a favorable impression of marine scientific research that would result in continued, or perhaps more appropriately – refreshed, freedom of research. The scientists saw their discipline as one that advanced the greater knowledge of mankind - one that (allegedly) enjoyed those special freedoms accorded "scientific, religious, or philanthropic missions" under previous sea law regimes.

With minimal courtesies to coastal states regarding the nature of their studies, scientists of the nineteenth and early twentieth century referred to by Colombos and Smith enjoyed broad freedoms of research. But scientific missions had been few and far between prior to World War II and provided little fodder for controversy. For a time after the War, scientists still enjoyed a great deal of freedom in the

conduct of research cruises. Notifications to coastal states were informal and often consisted of simple communiqués delivered through foreign marine scientists regarding the nature of work to be conducted. Science worked (and theoretically today *works*) through the free exchange of ideas and liberal debate of theory. That seemed to be enough.[217]

With the institution of the 1958 Conventions on the Law of the Sea, the first erosion of what appeared to the scientists as a bedrock notion of free access and movement began. Scientists were expected to *formally* notify coastal nations of their intent to conduct research in the waters offshore. The notion that science might be restricted if it impacted directly on economic exploitation of resources (living or non-living) crept into the equation. The idea that clearances hinged upon the "fundamental" or "pure" nature of scientific research and that a requirement of "open" publication existed, indicated that ocean science had acquired less than altruistic connotations. Obligatory offers of research opportunities to host nation scientists and requirements to share cruise samples and data as a condition of receiving clearance impinged on scientists' flexibility with cruise planning, the operational conduct of research cruises, the nature of the research, and the publication of findings. Ostensibly, restrictions on marine scientific research should not have been widespread - only a limited number of nations ratified the Convention on the Continental Shelf, the only one of the four 1958 Conventions to specifically mention marine scientific research. Just forty-five of the eighty-six nations that attended the Geneva conference signed the treaty; by 1971, only thirty-three states were parties to the treaty. But the precedent of coastal state "interference" that had been established by the Convention on the Continental Shelf was not only reserved by or confined to those nations that signed the Convention or adhered to treaty norms.[218]

From the outset, marine scientists were concerned with the prospects for bureaucratic interference because of the mention of their discipline in the1958 Convention of the Continental Shelf. The ICSU offered in 1958 to act as "honest broker" for marine scientific research proposals made to states parties to

[217] William T. Burke, *Marine Science Research and International Law* (Kingston: Law of the Sea Institute, 1970), 8.
[218] Ferrero, "The Latin American Position on Legal Aspects of Maritime Jurisdiction and Oceanic Research."

the Convention, by verifying whether or not research projects were *bona fide* fundamental scientific research that would lead to results for open publication. In addition, the organization proposed to ensure proper notification was provided the coastal state, and facilitate the participation of coastal state scientists. When the scheme did not meet with favorable response, the ICSU did not pursue it.[219] The International Council of Scientific Union's attempt to protect the integrity of marine scientific research was followed by similar efforts by the International Council for the Exploration of the Sea in 1964. Concerned that routine scientific sampling would be construed as economic exploration, ICES attempted to facilitate research access to coastal waters by proposing a registry for survey vessels. These ships would receive general permissions to conduct routine marine sampling in the waters of ICES member states, subject to specific restrictions on seismic surveys and without prejudice to rights of member states under the Continental Shelf Convention. The International Council for Exploration of the Sea's proposal also failed to gain support to realize implementation.[220]

Argument may be made over whether apprehension was worse than reality. Despite some evidence of clearance denials, on the whole the marine science community could not argue that the treaty had *significantly* dampened the ability to conduct research off foreign shores. Before the Convention raised the specter of a formal clearance process, the practice was marked by a lack of organized procedure. Record keeping was sporadic, making efforts to show any shift away from non-interference merely anecdotal, though previous freedom of research was a widely held perception. But it was possible that better record keeping was "responsible" for what scientists grumbled was a greater incidence of denials. United States scientists felt that a number of refusals were based on grounds more political than scientific. Elevated Cold War tensions and the polarization of nations into Western and Eastern camps also could have impacted the situation significantly. Countries were not above seeking leverage where they could between the superpowers. What was evident was that the bureaucratic process did little to facilitate the issue.

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[219] Alfred H.A. Soons, *Marine Scientific Research and the Law of the Sea* (Deventer: Kluwer Law and Taxation Publishers, 1982), 87.
[220] Ibid., 88-89.

The United States State Department directed U.S. scientists to submit clearance requests through its administrative process. On occasion the State Department denied requests without even forwarding the information, either because it felt from prior experience with the country in question that the effort was futile or would be regarded as a favor entailing U.S. responsibility to reciprocate politically, or because the United States did not have relations with the coastal State in whose waters the scientists wished to conduct research. The status of maritime sovereign and jurisdictional claims made by coastal states made a definite difference to this process. If the state asserted a sovereign or jurisdictional limit that the United States did not recognize as valid, the State Department would not forward the clearance because of the precedent of recognizing such a claim. The scientist was faced with either dropping his request, or modifying his research plan to defeat this bureaucratic-diplomatic Catch-22 by including "relevant" research *within* a region that the United States acknowledged as under the influence of the coastal nation and subject to a reasonable request for clearance to conduct scientific research.[221]

Efforts by individual scientists and international organizations to mollify the concerns of coastal states made little progress through the 1960s and well into the Law of the Sea negotiations of the 1970s. Warren Wooster, a professor of marine studies at the University of Washington, reported just before the final Session of the Third United Nations Conference on the Law of the Sea that U.S. scientists had been denied permission to conduct research in foreign coastal waters in more than one quarter of cases between 1972 and 1978. Nearly one third of all requests had encountered some form of impediment; better than half of the denials occurred for no evident reason. In some cases requests for additional information or delays in approval right up to the intended date of the research effectively scuttled them. With ship time running into the tens of thousands of dollars in operating costs per day, this was as fiscally difficult as it was distasteful and irrelevant to science. Wooster made no effort to quantify what percentage of research under consideration was dropped in the planning stages with regard to the State Department's position or

[221] Paul Fye, John Knauss, Warren Wooster, and William Burke, "The Marine Scientific Research Issue in the Law of the Sea Negotiations," *Science* 197, no. 4300 (1977); Judith A. Kildow, "Nature of the Present Restrictions on Oceanic Research," in *Freedom of Oceanic Research: A Study Conducted by the Center for Marine Affairs of the Scripps Institution of Oceanography University of California, San Diego*, ed. Warren S. Wooster (New York: Crane, Russak, & Company, Inc., 1973), 22-24; Wooster, ed., *Freedom of Oceanic Research: A Study Conducted by the Center for Marine Affairs of the Scripps Institution of Oceanography University of California, San Diego*.

expected obstacles from foreign countries, but he felt it was significant. He estimated that almost half of the work of U.S. oceanographic institutions (in the early 1980s) was in the 200-mile zones off the shores of foreign countries.[222]

Looking to the imminent Law of the Sea Convention (UNCLOS III), Wooster predicted that some difficulties might be alleviated by the terms of the Convention, but felt strongly that the predominant effect would be the further subjection of clearances to politics instead of science.[223] Wooster's study grew from concerns that he and other scientists had voiced in a 1977 report of the Ocean Policy Committee of the Commission on International Relations of the National Academy of Sciences. That report alleged that delegates at the Law of the Sea Conference were "more concerned with national pride, national rights, and national resources than with the 'common heritage' concept." The report cited examples where scientific investigations of monsoon conditions in the Indian Ocean, upwelling events on the west coasts of Africa and South America, and geologic studies on the east and west coasts of Africa and in the Arabian Sea were all severely impacted by refusals of various States to grant permission to foreigners to conduct research in their coastal waters. Based on the records of the University National Oceanographic Laboratory System, the coordinating consortium for the universities in the United States that maintained schedules for oceanographic ships, the Ocean Policy Committee stated that over half of the previous year's requests had been denied outright or subjected to hindrance sufficient to prevent the cruise. The result, the Committee felt, would be that "urgently needed research on pollution, fisheries management, and the understanding of climate, will not be undertaken in the economic zones of countries that are consistently difficult to deal with."[224]

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[222] Warren S. Wooster, "Ocean Research Under Foreign Jurisdiction," *Science* 212, no. 4496 (1981). With little but anecdotal evidence from earlier oceanographic cruises to analyze the impact of clearance requirements, scientists paid more attention to record keeping once this became a matter of negotiations under the Law of the Sea.
[223] Ibid.
[224] Fye, Knauss, Wooster, and Burke, "The Marine Scientific Research Issue in the Law of the Sea Negotiations."

Longing for the "freedoms" of the "old days" when science was the chief consideration for planning research cruises, marine scientists chafed at even the perception that their work was being restricted, as well as at those occasions when research requests were in fact impacted by the increased bureaucracy. Adding to their frustration was the confusing nature of requirements placed upon "private" and "public" research vessels. Ships sponsored and operated by universities with private funding were exempted from the formal process of submitting requests through the State Department, although clearance of some nature was still necessary through other channels or the researcher risked whatever response the coastal state felt justified in making to confront the incursion into coastal waters. But many universities operated ships owned by the Navy or another government agency with public funds (a very common method of overcoming the large capital expense presented by seagoing research); these vessels fell under the State Department scheme.

An even more confusing situation involved operators of government owned ships that used private operating funds; these ships fell in a gray area that some argued allowed them freedom from the government clearance process, but still provided them the sovereign protections accorded to government vessels operating in foreign waters. Still another scenario offered the possibility of privately owned vessels operating under government contract. Foreign governments, meanwhile, were at their leisure to make whatever judgment they felt about the nature of a ship's identity (of ownership/operating status) with respect to the clearance process for a ship to operate in waters under their jurisdiction. Even a semi-competent bureaucrat would have little difficulty delaying the processing and approval of a request past the point worth pursuing by the marine scientist. Regardless of the ownership or sponsorship of a research vessel, enough bureaucratic delay in the clearance process was sure to scuttle a research cruise considering the necessary preparatory lead-time and scheduling difficulties for shipboard research. With daily operating costs well into five figures, researchers and their university or government sponsors would not

risk moving ahead with survey plans until clearance issues appeared headed towards a reasonably timely resolution.[225]

Marine scientists also rued the loss of flexibility that invigoration of clearance norms and procedures imposed upon research cruise opportunities. The phenomena of interest to marine scientists varied temporally and spatially, but whether those phenomena were physical parameters of the water column or free-floating or swimming biologics, they invariably ignored existing political boundaries (save those very few borders that fortuitously coincide with a barrier that impedes fluid flow). In order to obtain funding and ship time, scientists generally had a reasonable feel for the extent of seagoing research necessary to investigate theories (assuming sound hypotheses) in order to submit survey intentions to coastal states, but it was not uncommon for researchers to encounter phenomena that did not conform to survey plans either in extent or duration. If forced to wait for clearance after modifying previously approved survey plans, to adjust to conditions encountered on station, or if the oceanographic parameters of interest extended into waters where they were not cleared (and possibly would never be cleared) to go, many research opportunities would be lost at great expense of time and money. To scientists who believed that their research interests were in the best interest of "advancing knowledge," no greater frustration existed. Additionally, "mechanical difficulties" could totally upend a cruise if it meant that the ship's schedule or intended research plan needed alteration, and the changes subsequently required submission of clearance modification requests through the coastal nation's approval process, a procedure that seldom responded in timely fashion. Moreover, adjusting survey plans to meet political rather than scientific needs was anathema for scientists, and maddeningly dependent on political factors. Faced with the prospects of even more rigorous coastal control over research, and little likelihood for a "return" of scientific freedom, marine scientists looked with little relish at the prospects for their discipline in the negotiations for UNCLOS III.[226]

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[225] Kildow, "Nature of the Present Restrictions on Oceanic Research."; Michael Redfield, "The Legal Framework for Oceanic Research," in *Freedom of Oceanic Research: A Study Conducted by the Center for Marine Affairs of the Scripps Institution of Oceanography University of California, San Diego*, ed. Warren S. Wooster (New York: Crane, Russak, & Company, Inc., 1973).

[226] Burke, *Marine Science Research and International Law;* Warren S. Wooster, "International Cooperation in Marine Science," in *Ocean Yearbook 2*, ed. Elisabeth Mann Borgese and Norton Ginsburg (Chicago: The University of Chicago Press, 1980).

The International Law Commission did not develop a draft set of articles for consideration by the Third United Nations Conference on the Law of the Sea as it had done before the 1958 Conference. Nevertheless preparations had been set in motion even before the creation of the initial Seabed Committee. Countries with similar concerns met to discuss their mutual interests in the Law of the Sea. International and intergovernmental organizations with a stake in the process, such as the Intergovernmental Oceanographic Commission, met to review proposals for convention language and strategize positions to be supported through national delegations to the Conference. Three subcommittees were established in the Seabed Committee to prepare the various subjects to be undertaken at the Law of the Sea Conference in more manageable divisions. Delegations, coalitions, and organizations worked to get their interests integrated into the texts worked on by the three subcommittees.[227] The United States' position on marine scientific research generally hewed to the concerns of marine scientists and was fairly representative of other nations that maintained oceanographic fleets or survey capabilities. Agreement with the US position in some cases crossed sharp political ideological lines. The Soviet Union, with vast oceanographic capability and a common, if opposed, interest in the oceans for military reasons, maintained a stance close to the American position with some exceptions with respect to its own continental shelf - at this point in the Cold War, strange bedfellows indeed. Opposed to the idea of unrestricted freedom of marine scientific research was a large bloc of the lesser-developed world.[228]

Latin American countries determined early on to protect their own interests and resources in their coastal waters, acting not long after the Truman Declaration of 1945 to extend the limits of their territorial seas. Chile, Ecuador, and Peru signed the Santiago Declaration in August 1952, extending both jurisdiction and sovereignty to two hundred miles off their coasts. This move by the CEP countries was followed by similar claims by El Salvador in 1962, Argentina in 1966, Panama in 1967, Uruguay in 1969 and Brazil in 1970. Mexico, Colombia, Venezuela, the Dominican Republic, and Guatemala had ratified and followed the norms of the 1958 Convention of the Continental Shelf and did not make excessive territorial

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[227] Soons, *Marine Scientific Research and the Law of the Sea*, 104-105.
[228] Wenk, *The Politics of the Ocean*, 280.

assertions. Recognizing the desirability of a unified position, in August 1970 twenty Latin American states met at the Latin American Meeting on Aspects of the Law of the Sea in Lima, Peru.[229] Where these countries had differences, most notably in the extent of their claims over coastal regions, they had overriding interest in presenting a common front and crafted a position with respect to marine scientific research that did not interfere with the particular national limits established by each country.

The Lima Declaration emphasized "the inherent right of the coastal state to explore, conserve, and exploit the natural resources of the sea adjacent to its coasts, and the soil and subsoil thereof."[230] It further highlighted the right of the coastal state to establish the limits of its maritime sovereignty or jurisdiction and to make laws to govern these areas. The Latin American drafters of the Lima Declaration were careful to ensure that "the position taken on oceanographic research is [was] completely linked with all the political and economic problems of the sea." Latin American States did not view freedom of scientific research in the same manner as oceanographers from countries such as the United States that favored an open regime and made their views clear, "The 'freedom' of scientific research, as asked by scientists, would be dangerous to the legal position of maritime sovereignty and jurisdiction of coastal states. Even more, such 'freedom' would go against the principles of sovereignty and jurisdiction that sustain the Latin American position." The Lima Declaration linked marine science to larger issues of control over marine resources for coastal States: "The right of the coastal State to authorize, supervise and participate in all scientific research activities which may be carried out in the maritime zones subject to its sovereignty or jurisdiction, and to be informed of the findings and results of such research." The Declaration of the Latin American States on the Law of the Sea (the Lima Declaration) subsequently forwarded to the Seabed Committee was drafted by Argentina, Barbados, Bolivia, Brazil, Chile, Colombia, the Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru,

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[229] Ferrero, "The Latin American Position on Legal Aspects of Maritime Jurisdiction and Oceanic Research," 111-114.
[230] The 1970 Lima Declaration on the Law of the Sea in Oda, *The International Law of Ocean Development: Basic Documents*, 349-355.

Trinidad and Tobago, Uruguay, and Venezuela (Costa Rica was represented by an observer; Haiti did not attend).[231]

The final resolution of the Lima Declaration incorporated a more forceful statement within its elaborated vision regarding marine science. Resolution 5 – On The Legal Aspects of Scientific Oceanographic Research, claimed the right of positive formal consent (or non-consent) over the conduct of marine scientific research in the waters of coastal states; the right of coastal states to participate and benefit from the results of that research; to own scientific samples and data; and reaffirmed that scientific research would be of a strictly and exclusively scientific character (i.e., not resource exploration). But philosophically the Lima Declaration went further, recommending "that these Governments adopt a common stand on the question of the desirability of those matters being considered jointly in the United Nations, so that the developing States, and particularly the Latin American countries, may participate actively in the formulation of any rules it is desired to adopt…." In the view of the Latin American countries, international organizations had "been composed [of] and influenced primarily by members of the developed countries." Through Resolution 5, the Latin American States asserted "their right to be included within these international organizations…[and that they]…have the will to participate actively in the formulation of any rules which will be adopted in the various forums dealing with the legal problems of scientific research on the oceans."[232]

Latin American delegates to the Seabed Committee made evident that they were "conscious of the experiences of history and know that most of the past rules of international relations have been established by a small number of powerful states in order to favor their own national interests." The Peruvian delegate attacked the United States' desire to achieve the greatest possible freedom for the investigation of open ocean areas as well as those close to the coasts of other countries, questioning why such freedoms should be achieved at the sacrifice of the rights of other countries in order to promote the "special interests and prosperity of the United States." He pressed the attack further, asserting that the United States had been

[231] Ibid.
[232] The 1970 Lima Declaration on the Law of the Sea in Ibid., 354-355.

“so bold as to interpret what they considered to be in the interests of other nations…. But the developing countries did not need to be told where their own interests lay; in that respect they were already sufficiently developed.”[233] Even though Resolution 5 of the Lima Declaration was about marine scientific research, it was clearly about growing national (and regional communal) awareness in the international system as well.

The Seabed Committee met throughout 1969 and 1970 and established a Legal Sub-Committee and an Economic and Technical Sub-Committee to focus expertise on the two main aspects of its mandate: to define the legal principles and the ways and means of promoting the exploitation and use of seabed resources, and to propose cooperative measures to prevent pollution of the marine environment from seabed activities. Marine scientific research received attention early in the process. The United States, the United Kingdom and France submitted proposals for the establishment of a legal regime for the deep seabed, the first two of which addressed marine scientific research.[234] To situate the discipline properly within a regime, Legal Working Group Members discussed the need to differentiate the “purely scientific” aspects of marine scientific research from the economic exploitation of resources, an arena for disagreement that remained long into the future negotiations of UNCLOS III. The need for differentiation had first been suggested by the wording of the 1958 Convention on the Continental Shelf, one of the ambiguities scientists recognized that threatened their “traditional” freedoms.[235]

Though a decade had passed, the international community was no closer to a resolution on the definition when the Seabed Committee was formed. The International Council of Scientific Unions had worked on the issue since the First Geneva Conference; in 1968 the ICSU’s Scientific Committee on Oceanographic Research had urged member governments to interpret liberally the marine science implications of the 1958 Conventions, but the ICSU appeared to have had little influence on state practice. Similar efforts were made by the International Council for the Exploration of the Sea in 1964 at the time the Convention on the Continental Shelf came into force and by the Working Group on Legal Questions Related to Scientific

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233 Ferrero, "The Latin American Position on Legal Aspects of Maritime Jurisdiction and Oceanic Research," 108-109.
234 Soons, *Marine Scientific Research and the Law of the Sea*, 104.
235 Ibid., 102-104.

Investigations of the Oceans of the Intergovernmental Oceanographic Commission in 1967, but to no avail. The scientific concern of SCOR, ICES, and the IOC paled before national interests intent on maintaining maximum control over seafloor resources.[236]

Negotiating responsibilities at The Third United Nations Conference on the Law of the Sea were distributed among three committees following a division of labor that was effectively the same as had been apportioned among the three subcommittees of the Seabed Committee. Marine scientific research and its corollary, marine technology, were assigned to Committee III along with the environmentally and politically sensitive issue of marine pollution. Committee I was tasked with determining a regime for the seas beyond national jurisdiction (the region known from earlier General Assembly Resolutions as the "Area") that included regulations for the mining of the seabed, the contentious issue that had done so much to instigate UNCLOS III, and agreement on the structure of an international agency to administer this harvest of the "common heritage of mankind." Committee II was charged with everything that remained, the "traditional subjects of maritime law: territorial seas, straits, islands, archipelagos, the high seas, an economic zone for living and nonliving resources adjacent to the coastline, the continental shelf, and access to the sea, especially by landlocked nations."[237] The tasks of Committee III depended heavily on the success of the other two Committees at resolving the issues they faced. Regulations for marine science and pollution were dependent upon the sovereignty and jurisdiction accorded coastal states through the determination of limits on territorial seas and economic exclusive zones negotiated by Committees I and II.[238] Marine scientific research was interwoven among the various articles negotiated by all three drafting Committees of the Law of the Sea.

About one-third of the Law of the Sea Convention's 320 articles referenced oceanographic research, scientific management of resources, training of research personnel, or marine science as it applied to

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[236] Ibid., 87-90.
[237] James K. Sebenius, *Negotiating the Law of the Sea*, Harvard Economic Studies, vol. 154 (Cambridge: Harvard University Press, 1984), 12-13.
[238] Robert L. Friedheim, *Negotiating the New Ocean Regime* (Columbia: University of South Carolina Press, 1993), 174-175.

protecting the marine environment.[239] This was not surprising, given the growing ability of science to affect various maritime interests, but also embodied a desire of coastal states to restrict long-distance research activity in response to the growing perception that marine scientific research was conducted with less than egalitarian motives. The relevance of marine scientific research and technology with respect to the deepsea challenges and issues of the Area and marine mining considered in Committee I was fairly evident. Similarly, various disciplines of marine science, hydrography chiefly among them, were integral to the descriptive efforts to delimit territorial boundaries and accurately determine the geographic and geophysical boundaries according to definitions negotiated in Committee II. Also evident with respect to the subjects considered by Committee II was that effective management, conservation and utilization of living resources was oxymoronic without an underpinning of scientific research. Where the science behind the emerging issues of the continental shelf and open oceans negotiated in both the First and Second Geneva Conferences of 1958 and 1960 remained shrouded, it was made clearly evident in the Third Law of the Sea Conference. Still, the treaty articles negotiated in Committee I and in Committee II largely treated scientific research as a facilitating implement or underlying principle rather than as a regime to be delimited by formal agreement with procedures, definitions, and boundaries. That task was relegated to Committee III and eventually codified by Part XIII of UNCLOS III.

Negotiations within Committee III were largely divided on North-South lines. Developed nations with sea-going research capabilities and established marine science programs (and significant maritime and military interest in establishing an open regime) contended with lesser-developed and newly established nations emerging from colonial domination, countries with limited capacity to appreciate the importance and relevance of marine scientific research, and still less ability to conduct it even in their own (emergent) territorial jurisdictions.[240] The United States and other oceanographically capable nations wished to establish an unfettered regime for marine scientific research. The developing nations wanted research to take place in their waters only with their consent and subject to other conditions. Freedom of scientific research was not, however, strictly an issue focused in coastal regions of the oceans. Integral to the

[239] Renate Platzoder, *The 1994 United Nations Convention on the Law of the Sea: Basic Documents with an Introduction*, Nijhoff Law Specials (Dordrecht: Martinus Nijhoff Publishers, 1995).
[240] Ibid.

negotiations for a regime for the deep seabed that took place in Committee I was the conduct of research on the high seas and on the seafloor of the Area (related to the mineral resources that comprised the "common heritage of mankind"). Unfettered research in the Area by developed nations would put the yet-to-be-established regulatory regime at a disadvantage when registering claims and while developing the capability of a collective organization to mine the seafloor: the golden goose dream of developing nations known as the Enterprise.[241]

Some motion towards reconciliation of positions was required to hammer out the twenty-eight articles that eventually comprised Part XIII of UNCLOS III. In addition, a great deal of coordination and negotiation was required between Committees I, II, and III with respect to mentions of marine scientific research apart from Part XIII, though much of it was definitional, to ensure coherence between articles separately negotiated by the different Committees. That coherence did not flow intuitively from Committee III. When its members met to iron out the differences over a regime for marine scientific research, they dealt with fundamentally opposing positions.[242] Central to the debate in Committee III was confusion and disagreement over what comprised marine scientific research. With definitions so important to the impact of treaties, debate raged over what constituted "pure" and "applied" research. Already apparent were the intimate connections between oceanography and naval applications as well as the commercial potential of the science to explore and exploit hydrocarbon and mineral resources. Discerning the line between pure and applied research was as difficult as constraining geophysical phenomena to political boundaries. Various formulations that were offered included the open publication of results as a discriminating factor. Academics argued that publication ensured the advancement of science and was fundamental, differentiating purely scientific efforts from those of private investigative endeavors linked to turning a profit from the information garnered in the water column and from the seafloor and subsoil. This argument held little water with coastal states. By and large these states possessed little ability to judge for themselves the merits (and veracity) of research proposals, but regardless did not desire open publication of

[241] Friedheim, *Negotiating the New Ocean Regime*, 176-177.
[242] Uwe Jenisch, "A Comparative Study of Current Draft Conventions and Proposals for a New Ocean Regime from the Point of View of Scientific Research," in *From the Law of the Sea Towards an Ocean Space Regime*, ed. Eckart Bohme and Max Ivers Kehden (Hamburg: University of Hamburg Press, 1972).

information that some enterprising engineers or scientists of other countries could possibly use for commercial or military purposes or profit outside the lofty advancement of knowledge.[243]

The First Session of the Law of the Sea Conference began in New York in December 1973 with procedural matters related to the organization of the Conference. Among the more important principles that emerged from the First Session was the agreement that texts would be adopted by consensus, that voting would occur on specific issues only upon failure of all means to reach consensus. Consensus was *not* defined to mean agreement, but the absence of overt dissent; abstention would not block adoption of an article. The Conference decided to adopt a "package deal" approach in which no issue was formally resolved until all others were as well, "…no question could be put to vote unless the whole range of problems was ripe for voting." Substantive negotiations, however, were not realized at the First Session.[244] The following summer in Caracas, Venezuela, the Second Session began negotiations with draft work inherited from the three subcommittees of the Seabed Committee. The Seabed Committee had failed to formalize draft articles prior to its dissolution at the start of UNCLOS III, but did produce numerous issue papers on Law of the Sea topics of discussion. Early in the process, Committee III reached agreement on general principles favoring the conduct of marine scientific research, but failed to agree on a formal definition that described its particulars. Moreover, the Committee failed to reach consensus on governing principles for a regime beyond territorial seas and on the role of the International Seabed Authority (ISA - the Organization under discussion in Committee I to oversee the exploitation of the deep seabed) in regulating research in the Area. These failures were not orphans - neither Committee I nor II made substantial progress at resolving their issues in Caracas.

Debate at UNCLOS III showed the fundamental importance to states of ensuring their interests in international negotiations. Opposition to scientific freedom in the oceans was not so opposed to *science* as it was to inroads on asserted national rights and access to and control over marine resources. Marine science had been caught up in the fray for two reasons: because it legitimately influenced and affected

[243] Ibid., 141-154.
[244] Soons, *Marine Scientific Research and the Law of the Sea*, 108.

issues dear to any nation: national security and economic advantage; and because the freedom of scientific research was something the developed nations of the North wanted! Juxtaposed the issues were extremely hard to combat. But what made the situation more difficult was that restrictions on marine scientific research could be argued on the merits as well as used as leverage against the North on other issues. The Lima Declaration established the critical link between marine science and an even more fundamental argument at the core of the Law of the Sea fight: how could freedom of scientific research be allowed to threaten the *sovereign* rights of a nation in its home waters?

Despite these rather substantial impediments, American marine scientists rallied in the name of science to fight for the freedom of ideas and knowledge, but it is not clear that they ever succeeded in lodging marine scientific research as a legitimate and substantial interest in the mind of US negotiators. Little doubt existed that the main concern of the United States in the Law of the Sea negotiations was freedom of navigation and transit for its naval assets around the world in the Cold War standoff with the Soviet Union. Not far behind were the economic concerns of the various lobbies with leverage in Washington: fishing, shipping, petroleum, and mining industries.[245] It was unlikely that freedom of scientific research - an abstraction at best, and visibly more a drain than faucet for funds – would prevail if pitted against any such interest. The best hope of marine scientists was that the more prominent issues might be pitted against one another and that their small piece of the puzzle would be left to more lofty and esoteric debate. It was not to be.

Battered by the trends of negotiations in the first sessions, the hopes of marine scientists were dashed by actions taken by the United States Government - entirely separate from the Law of the Sea negotiations - that did little to allay concerns about the possible clandestine nature of marine science activities for economic and military motives. The first event to rock the sanctity of the position of U.S. marine scientists approached the level of science fiction. Much of the international concern that led to the Third Law of the Sea Conference was over the exploitation of manganese nodules. Ambassador Pardo's speech

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[245] John A. Knauss, "Marine Science and the 1974 Law of the Sea Conference," *Science* 184, no. 4144 (1974).

was born of the issue and relied heavily upon it in convincing the nations of the world that international action was required quickly before the industrialized nations scooped (literally) the profits from the seafloor without any profit ever reaching a developing nation. Subsequently, the Seabed Principles Resolution of 1970 had directed nations to desist from further action to exploit the resource until international agreement was reached over a regulatory regime. The United States appeared to respect those norms. Into the fray sailed the *Glomar Explorer*.

Built (nominally) by Howard Hughes to mine manganese nodules from the ocean floor, *Glomar Explorer* put to sea in 1974 to conduct experimental tests in the Pacific. Law of the Sea Conference delegates became furious. The United States had heedlessly ignored the 1970 UN General Assembly Resolution 2749 (XXV) to abstain from new seabed initiatives until international controls were in place, to reap for itself the common heritage of mankind. Presented with what appeared to be a blatant disregard for international norms and an equally flagrant resource grab, delegates at the 1974 UNCLOS session had undeniable evidence of the need for a regime to govern an area that lay vulnerable to the technology of industrialized nations.[246] The situation (for U.S. scientists) only got worse. In 1975, it was revealed that the *Glomar Explorer* was *not* built by Howard Hughes and was *not* mining manganese nodules. It *was* however a top secret CIA ship designed to reach four miles into the Pacific in an attempt to recover a sunken Soviet submarine and the nuclear tipped missiles it carried.[247] The reputations of marine science and technology as benign pursuits were further maligned.

The ramifications of *Project Jennifer*, as the *Glomar Explorer* operation was known, were staggering. The United States had earlier suffered a blow to its prestige and credibility when an electronic eavesdropping ship, *USS Pueblo*, had been seized by North Korea. The crew was held for almost a year and the ship was never returned. The U.S. cover story for *Pueblo* was that she was conducting oceanographic research. This public embarrassment and revelation of the duplicitous use of "oceanographic research" as a cover for espionage did no favors to marine science. *Project Jennifer* did

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[246] Broad, *The Universe Below*, 256-257; Sanger, *Ordering The Oceans*, 126-128.
[247] Broad, *The Universe Below*, 78-80.

even more damage. On the face of things, the United States appeared arrogant to use for a cover story a scenario that affronted the entire world instead of only deceiving its primary adversary, the Soviet Union. But where that deception ended, and after connotations for the use of the ship for intelligence purposes (à la *Pueblo*) also fell away, what remained was technology so spectacular that it struck fear in developing nations. The United States had built a ship that could reach *four miles* into the ocean to recover an entire submarine. The technological gap between the developed North and the underdeveloped South was never so wide, and the delegates knew it.[248]

Ironically the state with perhaps the greatest interests in the preservation of freedom of marine scientific research, the United States had inestimably damaged those very prospects and firmed coastal states' resolve to determine what took place on their oceanic flanks. Argument that scientific research was beneficial to coastal nations appeared casuist at best, callously and arrogantly calculating otherwise.[249] Speaking to a conference of hydrographers in 1979, Leonard Legault summarized the reluctance of coastal States to allow the freedoms the US and other oceanographically capable states desired:

> Because they understand the economic uses of marine research, they view freedom of research as a pathway for the erosion of their sovereign rights over the resources of the economic zone… Perhaps they forget that you do not gain freedom in one field by denying it in another. But I am sure they are right in saying that 'pure' research is a rare thing: Einstein and a piece of chalk – but that led to the atomic bomb. Knowledge is power, they say; and who can disagree? How, they ask, can they manage their resources if those wishing to exploit them know more about them than they do? How can they bring about a real transfer of technology if they cannot participate meaningfully in all research within their economic zone? And how can they truly participate without control?[250]

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[248] Jonathan A. Walz, "Marine Scientific Research and the Transfer of Technology," in *Major Issues of the Law of the Sea*, ed. David L. Larson (Durham: The University of New Hampshire, 1976), 173.
[249] Alfred P. Rubin, "Sunken Soviet Submarines and Central Intelligence; Laws of Property and the Agency," *American Journal of International Law* 69, no. 4 (1975): 855-858.
[250] Sanger, *Ordering The Oceans*, 128.

Testimony presented to the United States Congress after the Third UNCLOS Session in 1975 summarized the concessions the United States and its allied oceanographically minded States were prepared to offer to balance freedoms of scientific research against coastal states' interests, acknowledging seven obligations of research scientists: (1) the requirement for advance notification of the proposed research together with a detailed description; (2) the right of coastal state participation; (3) the sharing of all data and marine samples with the coastal state; (4) assistance in interpreting research results; (5) open publication of results; (6) compliance with all applicable international environmental standards; and (7) flag state certification that research would be conducted in accordance with the treaty by a qualified institution with a view to purely scientific research.[251] For their part, coastal states of the developing world harbored a number of concerns over the need to maintain control over scientific research: (1) to be the final arbiter of the kind of research they believe would be of benefit to their state; (2) fears that unregulated research would widen the technological gap between developed and developing nations and the perception that only advanced countries could translate scientific research into economic benefits or military power; (3) fear for espionage activities by research vessels (the *Jennifer-Pueblo* syndrome); and (4) the absence of a *quid pro quo* in return for allowing foreign researchers to conduct oceanic research within waters near their coasts.[252]

The bureaucracy in Washington soon drove another nail in the coffin of marine scientists' hopes for a free regime of scientific research. The United States Congress passed and the President signed the

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[251] Robert E. Osgood, Ann L. Hollick, Charles S. Pearson, and James C. Orr, *Toward a National Ocean Policy, 1976 and Beyond* (Washington, DC: National Science Foundation, 1976), 14. The United States was generally supported by oceanographically capable states of the *West* such as Canada, France, the United Kingdom, and the countries of Scandinavia. On the one hand interested in access for oceanographic research, on the other the Soviet Union was hesitant to offer support to something that might enhance U.S. capabilities that already impacted the Cold War naval submarine confrontation. Eastern-bloc countries generally stood behind the Soviet Union's reticence to support as open a regime as the U.S. lobbied to create, especially with respect to (perhaps not unfounded) concerns regarding research anywhere on its continental shelf. Good contemporary views regarding the outlook for marine science during this period in the Law of the Sea negotiations may be found in Fye, Knauss, Wooster, and Burke, "The Marine Scientific Research Issue in the Law of the Sea Negotiations."; Knauss, "Marine Science and the 1974 Law of the Sea Conference." Specific positions and arguments are detailed in United Nations Division for Ocean Affairs and the Law of the Sea, *Marine Scientific Research: Legislative History of Article 246 of the United Nations Convention on the Law of the Sea* (New York: United Nations, 1994).

[252] Committee on Commerce, *The Third U.N. Law of the Sea Conference* (Washington, D.C.: United States Senate, 1975), 32-33.

Fisheries Conservation and Management Act of 1976, also known as the Magnuson-Stevens Act.[253] Although the United States did not unilaterally declare an Exclusive Economic Zone in its coastal waters until 1983, the Magnuson-Stevens Act effectively established one when it extended US control of offshore fisheries from twelve to two hundred miles. There was little argument that could be offered in opposition to a similar jurisdictional allowance for coastal states in general with respect to marine resources. The regime for marine scientific research, negotiated in the Law of the Sea Conference separate from the issues of the Exclusive Economic Zone but nevertheless dependent on the delimitation of coastal state jurisdiction that would be decided by negotiations for EEZs, withered under this blow. Some form of coastal state consent would prove necessary for the conduct of marine research because of the inherent, if not semantic, arguments that could be offered over the nature of scientific research (and its military or economic relevance) conducted by marine scientists within the EEZ of a foreign coastal state. Not wanting to risk more important issues negotiated in the Conference (the width of territorial seas, rights of innocent passage through territorial seas, and rights of transit passage through international straits and archipelagos), the United States was reluctant to contest the secondary issue of marine scientific research, especially with little hope of winning.[254]

That does not mean the United States would not still try to influence the negotiations. Writing for the U.S. civilian oceanographic community after the Sixth Session of the Law of the Sea Conference in 1977, the National Academy of Science's Ocean Policy Committee (NAS OPC) prescribed five essential objectives and five responsibilities that it believed needed to be acknowledged in any treaty concerning scientific research in oceanic economic zones. The treaty must: establish the right to conduct all but carefully specified (but not elaborated by the Committee) research beyond the territorial sea; provide predictability on clearance adjudication to facilitate cruise planning based on specific and objective criteria that identified what projects needed consent and under what conditions consent would be granted; secure protection from arbitrary or unreasonable restrictions; ensure predictability in the planning and conduct of research; and maintain the traditional practice of publishing and disseminating results. In return, the

[253] Wilder, *Listening to the Sea: The Politics of Improving Environmental Protection*, 156.
[254] Friedheim, *Negotiating the New Ocean Regime*, 176-177.

Committee acknowledged that all responsible oceanographic institutions must: keep coastal states fully informed concerning the nature, objective, schedule, and participants of the proposed research project; ensure the rights of coastal states to be represented; provide the coastal state with preliminary and final reports; share data and samples; and provide the coastal state assistance in interpreting results.[255]

The Seventh through Tenth Sessions of the Third United Nations Law of the Sea Conference shuttled between New York and Geneva over the next four years, producing a Draft Convention during the Ninth Session in New York that was later adopted as a formal Conference document at the Tenth Session in Geneva in August 1981.[256] Committee III made some changes to the regime for marine scientific research in the last four sessions, including formalization of the provision for implied consent by coastal states after a period of inaction by the state in considering a clearance request, but no dramatic shifts occurred. The marine science provisions of UNCLOS III ultimately included and expanded upon the responsibilities of research states detailed in the NAS OPC recommendations, but fewer rights were granted to research states and the marine science institutions they sponsored than the OPC hoped would result from the Law of the Sea negotiations. Coastal states, while enjoined to promote marine scientific research in general, were accorded unambiguous authority over the conduct of research in their territorial seas and considerable latitude to restrict the conduct of research in their exclusive economic zones under a positive consent regime.

The 1982 United Nations Convention on the Law of the Sea removed a great deal of the ambiguity surrounding the conduct of marine scientific research and clarified the privileges and responsibilities of scientists who wished to investigate the coastal waters of foreign nations. The high seas freedom of research that had been enjoyed since the days of *Challenger* and other early attempts to investigate the oceans remained largely intact; the main rejoinder to scientists was the requirement to respect the high seas freedoms of others. From the "implied" freedom of scientific research that the International Law

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[255] Fye, Knauss, Wooster, and Burke, "The Marine Scientific Research Issue in the Law of the Sea Negotiations," 230.
[256] Soons, *Marine Scientific Research and the Law of the Sea*, 115-118.

Commission had felt too obvious to state (and too insignificant to worry that those freedoms would be infringed upon) in the 1950s, marine science was elevated to a codified freedom of the high seas in article 87 - of course not without caveat. Article 87 stipulated that freedom of research on the high seas was subject to provisions of part VI (a reformulated version of the 1958 Convention on the Continental Shelf) and to the full elaboration of the marine science regime of Part XIII of the Convention. Though states were granted a great deal of autonomy over the continental shelf, they were still enjoined by article 78 of Part VI not to arbitrarily infringe upon the "rights and freedoms" of other states with respect to other activities on the continental shelf beyond the 200 mile limit of the Exclusive Economic Zone, but still within the somewhat liberal definition of the shelf (extending up to 100 nautical miles from the 2,500 meter isobath or to a maximum 350 miles from the baseline from which the breadth of the territorial sea is measured).[257]

Part XIII: Marine Scientific Research of UNCLOS III conveys to all states, regardless of their location, as well as to "competent" international organizations the right to conduct marine scientific research, together with a duty to promote and facilitate it compatibly with other rights conferred by the Convention. The General Provisions of Part XIII highlight the interwoven nature of marine scientific research with other provisions of the Convention; though avoiding specificity, the provisions imply a great deal of coordination was required by the three drafting committees to ensure coherence between regimes. The Convention states that marine scientific research is to be conducted for peaceful purposes, without interference with other legitimate uses of the seas and with respect for the protection of the marine environment. International cooperation is highly encouraged and states are exhorted to provide opportunities for international agreements that in turn would create favorable conditions for marine scientific research, integrate the efforts of scientists, and make results of research available to the international community.[258]

While UNCLOS III supports in theory the freedom and benefits of marine scientific research, it does not do so blind to the political realities of self-interest. Articles 245 and 246 convey considerable control over

[257] Platzoder, *The 1994 United Nations Convention on the Law of the Sea: Basic Documents with an Introduction*, 33-36.
[258] Ibid., 100.

research in coastal waters to the bordering states, the first acknowledging coastal state jurisdiction over territorial seas (with exclusive control over activities such as marine scientific research) and the second prescribing coastal state jurisdiction over research in 200-mile exclusive economic zones and on the continental shelf. Where research in any of the three subdivisions of the littorals requires the consent of the coastal State, research outside the territorial sea is afforded a small measure of protection from the arbitrary whims of a coastal state through an implied consent proviso to a positive consent regime. Notwithstanding their considerable autonomy, coastal states are encouraged to foster oceanographic research within their jurisdictions. Where little might be said regarding obligations of coastal states with respect to allowing research in waters over which they have prescriptive jurisdiction, in "normal circumstances" states are required by paragraph 3 of article 246 to grant research requests in areas of their jurisdiction beyond twelve miles for research that meets two criteria. The research must be exclusively for peaceful purposes and seek to increase scientific knowledge of the marine environment for the benefit of all mankind. The ultimate trump, however, is retained by the coastal State. Determining whether the nature of research described in a clearance request conforms to "peaceful purposes" or seeks to increase scientific knowledge for the "benefit of all mankind" is a subjective escape clause that empowers coastal States to act conservatively - well within the norms of the Convention - in their own self-interest.[259]

Although paragraph 4 of article 246 provides latitude for the definition of what constitutes *normal* circumstances, including situations where states do not maintain diplomatic relations, there is considerable room for states to deny access based on conditions they consider abnormal such as neighboring strife or other qualifying occurrence. But interpretive permutations of normal circumstances pale in the face of the ambiguity offered by the second caveat in paragraph 3 of Article 246… States are permitted considerable discretion to disallow access if it is determined that research is of direct significance for the exploration and exploitation of natural resources, whether living or non-living; that the research involves seabed drilling, explosives, or the introduction of harmful substances into the environment; involves construction or use of artificial islands or structures; if the state determines that misinformation has been communicated as to the nature of research; or there remain any outstanding obligations to the coastal State from a prior project that

[259] Ibid., 101-103.

may be the responsibility of the researcher making the request or *any other* researcher from the same state. Concessions are made to research states to allow for investigation (physically) on the continental shelf beyond exclusive economic zones in areas where the coastal state has not initiated or planned imminent exploratory or exploitive operations.[260] But research must be conducted without prejudice to the rights of coastal states established in Article 77 of Part VI: The Continental Shelf (the provision of the regime for the continental shelf that confers prescriptive jurisdiction over the shelf for purposes of exploration and exploitation of natural resources to the coastal state), and must not interfere with other activities of the coastal state in the exercise of its jurisdiction. Although confusing and ambiguous, especially considering the dual-use aspects of the great majority of scientific research, this implies some level of differentiation between exploration for economic purposes and *scientific* exploration or inquiry. Investigation in the water column, restricted within the 200-mile exclusive economic zone and as described on the continental shelf, is a freedom of the high seas beyond this limit.[261]

States and international organizations that wish to conduct marine scientific research in the exclusive zones of coastal states are also required by Article 248 to provide a considerable degree of information regarding research intentions and comply with certain conditions relevant to the conduct of the research. Six months in advance of the expected starting date, the coastal state must be provided a full description of the nature and objectives of the project; the method and means to be used, including the name, tonnage, type and class of vessels and a description of scientific equipment; the precise geographical areas in which research is to be conducted; the expected dates of appearance and departure of research vessels and any equipment involved in the research; the name of the sponsoring institution, its director, and the person in charge of the project; and the extent to which it is considered that the coastal State may participate or be represented in the project. Once accorded permission to conduct research, states and competent organizations must additionally comply with a number of conditions: the coastal state is accorded the right to participate in the project, including representation aboard vessels or other craft involved in the research, when practicable (availability of research opportunities is made known to coastal states when requests are

[260] Ibid., 102.
[261] Ibid., 32-33.

submitted, presumably so that the coastal state may consider its own opportunities for conducting research ancillary to the foreign research conducted as a factor in weighing approval of the request; regardless, the coastal state would be privy to the results of the foreign scientists' research), and without contributing toward the costs of the project; the coastal state shall be provided at its request all preliminary and final reports, results, and conclusions as well as data and samples that can be provided without detracting from their scientific value (most oceanographic samples, besides discrete organisms – and even then if multiple specimens are collected – can be divided, or agreement can be brokered over access to data and samples amenable to coastal state and research state needs); coastal states are to be provided assessments of data, samples, and results or assistance in conducting assessment or interpretation; research results must be made available internationally subject to coastal state consent that may be withdrawn even after the conduct of the research; coastal states must be informed of any major changes in the research plan and unless agreed otherwise, all research equipment and installations must be removed at the conclusion of the project.[262]

Even though UNCLOS III institutes a consent regime for research in areas that had been previously (in the absence of extended territorial claims) been open to investigation, creating an additional bureaucratic hurdle to be cleared, the Convention also provides a few loopholes to prevent a total barrier to marine scientific research. Articles 247 and 252 provide instances when the express consent of the coastal state is not required for research cruises to proceed. States and competent international organizations are allowed to proceed with investigations six months after submitting the information required by Article 248 through appropriate channels to the coastal state, unless within four months the coastal state informs the state or organization desiring to conduct the research that it has withheld its consent or requires additional information to reassess the request. Once a coastal state has met the four month response time required to indicate that its consent is not to be implied, but rather is contingent upon some additional information or other factors (assuming that denial has not ended the inquiry), there is no statutory time dictated by the Convention that the coastal state must then satisfy to consider a request. A coastal state may in effect, kill a request with bureaucracy, asking for repeated submissions of information until any number of factors precludes the conduct of scientific inquiry: the researcher decides that efforts are better spent elsewhere, the

[262] Ibid., 103-104.

phenomenon of interest (if temporally variable) has passed, flexibility in cruise planning recedes, or alteration of a cruise underway becomes no longer possible. While the consent regime clearly favors the coastal state, one of its provisions is more reasonably inclined towards research states and makes efforts by coastal states to deny access slightly less facile. In this circumstance, consent is implied in those situations where coastal states are members of international organizations or partners in bilateral agreements with organizations that wish to conduct research in their exclusive zones, and make no objection within four months of notification of the project by the organization or demonstrates its willingness to participate. Assuming the coastal state finds value in membership in the organization or advantage in the international agreement it is party to, consent is more likely than it otherwise might have been.[263]

Part XIII additionally directs in Article 250 that all contacts with respect to requests for access to conduct research be made through appropriate official channels rather than by *ad hoc* arrangements or via private institutions that would avoid providing the coastal state an opportunity to deny the request. Coastal states have the right under Article 253 to suspend research activities in progress in their exclusive zones or on their continental shelf if it is determined that any of the provisions of Articles 248 and 249, the requirements to provide the coastal state with relevant information and to adhere to certain conditions upon consent, are not met by the researching state. This right to require cessation is specifically delineated with respect to major changes in the scientific plan of research, or in the event that any of the discrepancies with respect to the provisions of articles 248 and 249 are not rectified within an appropriate period of time.

In an interesting, and certainly new twist to the arena of marine scientific research, neighboring land-locked and geographically disadvantaged states are accorded in Article 254 some of the same rights and privileges of notification, assistance, opportunity to participate, receipt of data, and assistance with the interpretation of data and results of the research. Participation of land-locked and geographically disadvantaged states is *subject to review and approval* by the coastal state after submission of the same information required of the research state by Article 248. No criteria are offered in Part XIII to determine

[263] Ibid., 103-105.

which states constitute this category of participation. While it is geographically possible to identify land-locked states that neighbor a coastal state, it is considerably less probable that universal agreement could or would be reached over which states in the region are geographically disadvantaged apropos the circumstances of this provision. The burden to satisfy the spirit of this mandate of Article 254 appears to fall most heavily upon the research state and offers considerable opportunity to run afoul of coastal state receptivity.[264]

Coastal states are encouraged to adopt measures to facilitate marine scientific research, but this provision, Article 255, lacks both incentive and provision for enforcement. All states and competent organizations are accorded the right to conduct marine scientific research in the Area and in the water column beyond exclusive economic zones, even above continental shelves that remain subject to coastal State jurisdiction. Installations and equipment used in any area of the marine environment in the conduct of scientific research are subject to the same constraints as scientific research in those areas. They must be properly marked identifying the owner and State of origin and possess appropriate safety warning beacons and signals; they do not possess the status of islands and must not provide obstacles to established shipping lanes.

The remaining articles of Part XIII: Marine Scientific Research, make states and competent organizations liable for the actions of their research programs and juridical persons. This liability extends to the research scientist's duties to properly inform the coastal state of any changes in survey intentions throughout the conduct of marine scientific research in its waters; to compliance with the requests and conditions imposed by coastal states upon granting approval for research (and concomitant duties with respect to neighboring land-locked and geographically disadvantaged states); and with the actual conduct of and damage resulting from research activity.[265] Disputes are subject to procedures for resolution elaborated in Part XV of the Convention: Settlement of Disputes.[266] Closely related to the stipulations of

[264] Ibid., 104-106.
[265] Ibid., 106-108.
[266] Ibid., 114-121.

Part XIII: Marine Scientific Research - both by association and in theory - are the provisions of Part XIV: Development and Transfer of Marine Technology. Though it is certain that little success would be realized in marine science without the proper tools and techniques, Part XIV is not an effective vehicle to facilitate or advance research activity. It is a largely toothless section of the Convention that exhorts states to promote, endeavor, ensure, cooperate, collaborate, disseminate, facilitate and otherwise support without any degree of enforcement the general development, transfer, training of personnel to operate, and implementation of marine technology for the benefit of lesser developed nations. While marine technology is integral to marine scientific research, the provisions of Part XIV offer few concrete accompaniments to the regime of Part XIII other than an elaborate vision of international scientific collaboration and harmony.[267]

Although decried by scientists for restrictions it places on "freedoms" of scientific research, Part XIII: Marine Scientific Research of the Third United Nations Convention on the Law of the Sea is more realistic than it is unreasonable. It may well be that science is no longer "free" in the most *laissez-faire* sense, but it is naïve to think that it would be. In a world where inter-relationships between the most esoteric of issues are sought and defined, it appears obvious that research by foreign governments or other entities in waters set aside for the exclusive economic use of coastal states would likely be opposed for its possible economic or national security implications. All the more so if the coastal state lacks the capacity to evaluate in depth proposals submitted for clearance and has no independent arbiter to vouch for the "pure" or "fundamental" nature of the research. Even if a research proposal satisfied such a criterion, the question of Einstein's chalk still lingers. Of particular concern is the vulnerability of coastal states in negotiations over exploration and drilling rights for hydrocarbon resources in a lopsided negotiation with industries armed with more data about their EEZ than coastal states themselves possess. Unless the research were framed in terms of direct benefit and interest to the coastal state – and dissemination and use by the research state restricted (denying almost *in toto* the relevance of conducting the research), the most basic question the government of a coastal state must ask in the interests of its citizens goes unanswered, "What's in it for us?" UNCLOS III codified what was largely becoming the practice of coastal states – the enclosure of a

[267] Ibid., 108-112.

wide swath of coastal waters for the exclusive economic use of the state. Of interest to both developed and developing nations, this practice exists at odds with the idea of free inquiry into the natural properties of the region. The consent regime established in Part XIII is a natural corollary to the idea of an EEZ.

Article 247 provides for the implied consent of a coastal state with respect to research projects - initiated by international organizations or as a result of bilateral or multilateral agreements that the state is a member of or party to - that are elements of a general research program the state has approved or is willing to participate in, and to which the state has not expressed any objection. This article makes a small concession to research states by encouraging coastal states to honor the goals of the organization or agreement it joined of its own will. Presumably the state would suffer embarrassment if it were not to uphold these commitments. This may well be the paradigm with the greatest chance of success from the perspective of research states and from the perspective of a global need to establish the causes and effects of global environmental issues. But it will succeed only if coastal states consider it is in their best interests to join and remain members of international organizations or become parties to treaties that can coordinate such research.

Reflecting back to the Latin American objections in meetings of the Seabed Committee, membership in organizations and having a say in the activities pursued by organizations is an important element for developing nations. Had they been able to voice their concerns effectively as members of international forums that tried to influence the formulation of draft articles to the treaty, it is possible that marine science might have been treated with more deference. With developing states relegated to the sidelines of the decision making process of international bodies, governmental or non-governmental, this moderating effect was lost to the contrary use of marine science as leverage, "[The]…right to pursue ocean science freely in the EEZ became a surrogate for myriad problems between the developed and developing states…the heat of the debate seemed to be out of proportion to the overall importance of issue."[268]

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[268] Friedheim, *Negotiating the New Ocean Regime*, 209-211.

Scientists who wish to conduct research in the coastal waters of foreign states would do well to consider the economic and national security implications of marine science. To deny these concerns is to overlook the case that catalyzed the Third United Nations Law of the Sea Conference: scientific investigation of the feasibility of economically exploiting manganese nodules. To be sure, the deft handling of the subject by Ambassador Arvid Pardo in his General Assembly speech was critical to raising the issue to international awareness in that case, but it is not inconceivable some new John Mero will write up research results in such compelling fashion to stimulate a new Arvid Pardo to elevate to international attention an altogether new resource of the sea. Scientists may view the dedicated pursuit of knowledge to be altruistic and may in sincerity harbor no ulterior motives beyond this goal; nevertheless, others may perceive it as scientific arrogance to hold the advancement of knowledge on a higher plane than the interests of those who may be directly impacted by the results. The difficulty of foreseeing which research may uncover new sources of academic or economic wealth makes erring on the side of caution a natural tendency for coastal states. Growing controversy over stewarding biodiversity and establishing intellectual property rights makes states hesitate before opening their boundaries to investigation and risking appropriation by others of something that could prove dear to their interests. The challenge to scientists seeking coastal state approval for research projects will be in identifying some aspect of marine research beneficial to the coastal nation and amenable to the research plan the scientists wish to follow in pursuit of their own research interests. What they will have to avoid however is the same perception that some delegates to the Law of the Sea Conference held of the one-sided benefit to marine scientific research in EEZ's: an "image…of the developed states' fully equipped research vessels hovering off the coasts of developing countries struggling to become new nation-states under severe handicaps, including lack of essential knowledge about their own patrimony."[269]

A great number of prominent issues of the 21st century are effectively global in impact, if not in origin. Whether the concern is global warming, ozone depletion, infectious disease, or international terrorism, it can be seen that without coordinated international effort, there exists little hope for an effective solution. Certain geographic centers exist pertinent to each of these issues in which the problem emanates, festers, or

[269] Ibid., 209.

becomes subject to a vicious feedback cycle that exacerbates the crisis locally, and then through various transmission vectors ultimately creates transnational crises. When issues are environmental or environmentally dependent, the search for solutions must focus first upon these geographic centers. The oceans are often central to such issues. The coastal regions above the continental shelf are both a great source of resources as well as natural sinks for various elements (such as carbon and nitrogen) that in extreme amounts are capable of destabilizing the entire earth system via their impact on hydrologic and atmospheric cycles. Since an overwhelming proportion of people in the world live within a few hundred miles of the oceans, their impact is felt in coastal waters via river outflows, atmospheric transport, or through direct input of byproducts and wastes of human activity.[270]

Concentration of terrestrial pollution in these regions endangers the region's capability as natural buffer and sink through disruption of the system's ecological links. To sample conditions *in situ* requires some latitude to pursue information according to the dynamics of the observed phenomena, across political boundaries. Of concern to marine scientists interested in these problems, Part XIII of UNCLOS III restricts access to the very regions most critical to scientific investigation. The ephemeral natures of most marine phenomena dictate the need for flexibility in the conduct of research. Bounded by the politics of research clearances rather than geophysical conditions, expensive seagoing research may come to naught for purely arbitrary considerations. Public awareness may help overcome these limitations; where few people outside the small academic community of oceanography knew about El Niño just a few years ago, the geophysical phenomenon's impact has reached a level of attention and concern that might overcome some of the political barriers that stand in the way of clarifying its parameters through marine science.

The unfettered ability to conduct marine scientific research, if it ever really existed, became a casualty of the Law of the Sea negotiations because of the very success it enjoyed in revealing the secrets of the

[270] It is estimated that two-thirds of the world's population of approximately six billion people live within 250 miles of the ocean. More than half of this number – some two and one-half billion people - live within 60 miles of the coast. Don Hinrichsen, "Ocean Planet in Decline," 2004 (accessed April 21, 2005); available from http://www.peopleandplanet.net/doc.php?id=429&section=6; *World Resources 2000-2001: People and Ecosystems: The Fraying Web of Life* (Washington: World Resources Institute, 2000), 72-73.

seas. Paradoxically it was the developing nations, largely unable to conduct dedicated marine scientific inquiry, which recognized and developed a growing appreciation for its importance to their economic and national security. Attempts to cast marine science in a more favorable light, asserting that it "advances knowledge" were seen as naïve at best, disingenuous otherwise. Ironically the United States, the nation that rose to maritime prominence in the 20th century in part because of the priority it placed on marine science to defeat its adversaries, was not willing to fight for unfettered access to areas of scientific interest in the protracted negotiations that stemmed in no small measure from the fruits of marine scientific research. The sea change for marine scientific research took place not long after the 1958 Geneva Conventions, when marine science illuminated new possibilities to exploit the oceans and coastal states realized the stakes; those states will continue to deny clearance if they feel their interests are threatened – whether the United States is party to UNCLOS III or not. Change will come not with a treaty, but when scientists convince coastal states by demonstrating that change is in their interest, and research is beneficial rather than threatening. And to do this the scientists must overcome a simple guiding principle that influences coastal states: once bitten, twice shy.

Science, Security & Sea Law

The application of ocean science to undersea warfare evolved over the course of the last hundred years to the point where it is no longer questioned that to fight effectively from the offensive or on the defensive in this niche of naval warfare, knowledge of the operating environment is indispensable. When undersea warfare first appeared during the American Civil War, surface navies were effectively defenseless; had the technologies had time to improve, they may have made an even greater impact for the South than they accomplished as it was. During World War I, Germany very effectively employed undersea warfare against Britain and her allies; effective anti-submarine tactics involving convoys and destroyer screens evolved, but these too realized limitations when the attacking platform could not be *located*. America entered the war at a critical point with enormous reserves of manpower and materiel, so it becomes difficult to speculate, but if German submarine technology had continued to evolve - especially in terms of weapons

range and reliability of torpedoes and the speed and endurance of the submarine itself - the advantage of stealth that the submarine enjoyed because of the opacity of the oceans might have tipped the balance.

Without this undersea threat that almost brought England to its knees in the First World War, concerted research efforts that eventually struck upon sound as the optimal underwater search method more than likely would have evolved merely incrementally as research into a means of navigational assistance and object avoidance. Only after considerable exertions in support of anti-submarine warfare were passive underwater hydrophones developed that were tactically sufficient for use by warships; and some years elapsed and considerably more testing was necessary before active sonar was developed in anticipation of the undersea naval conflict in the next World War looming on the horizon. And then only at the eleventh hour did it become clear that environmental knowledge was the key to developing sonar as a truly effective and reliable tool, and that tactical advantages accrued to the side that best operated according to the constraints imposed by the physical ocean environment.

The tactical benefit that oceanography provided in undersea warfare remained the driving requirement behind oceanographic investment throughout the Cold War that began immediately after World War II. This certainly remains true with respect to undersea warfare in the present day, and the United States Navy remains heavily invested in ocean science via the Office of Naval Research. As long as undersea warfare is an element of naval strategy, oceanography will play an active facilitating role as a force multiplier – making sensors and weapons perform better by revealing the parameters of the oceans that affect them, and providing the necessary insights for scientists and operators to develop new equipment and data processing techniques that make possible more effective utilization. A great deal of research in this vein is still necessary, as the oceans remain opaque to all but a few methods of search and each of those methods are subject to influences of the physical properties of the sea. If the undersea were somehow effectively removed as an element of warfighting strategy – unlikely, as even if submarine warfare were too advanced for certain navies, relatively cheap mine warfare and special warfare remains viable and both of these are subject to environmental constraints – perhaps naval warfare would return to the two-dimensional time-distance-firepower problem that it was before the third dimension was added. But even this simplified

vision of maritime warfare depends on real-time knowledge of environmental operating parameters to optimize performance of modern weapons and sensors, and ships continue to ply a medium that has yet to be tamed by man for his exclusive use. High winds and seas, currents, tides, and ocean storms are but some of the parameters surface naval forces contend with that are elements of the fields of ocean science. They cannot be ignored and they change continually, demanding constant vigilance by mariners.

A great deal was learned about the oceans as a result of oceanographic inquiry related to the challenge of undersea warfare. To investigate this largely unexplored realm, new instruments were developed to gather data and to probe the furthest reaches of the marine environment. Because of the myriad of physical parameters that influence the transmission of sound underwater, almost anything and everything that might impact underwater acoustics was subject to investigation. Surf action on beaches, tidal currents that disturb seabed materials, breaking waves at sea and rain upon the ocean surface provide sound interference at critical frequencies. Even marine biology became the interest of this scientific push as a result of the "squeaks, honks, clicks, groans, barks, and moans of marine life" that interfered with the resolution of underwater sound signals of interest.[271] The broad spectrum of research dramatically expanded mankind's knowledge of the sea and seabed, and in the process catalyzed interest in the potentially exploitable resources resident in the depths…with all the attendant consequences that issue engendered.

Oceanographic research that was undertaken to investigate one aspect of undersea warfare developed and refined capabilities that demonstrated useful military applications for others. Deep submergence capabilities via bathyscaphs and other undersea vehicles were leveraged for development of submarine search and rescue, underwater salvage…and deep sea espionage; it would be difficult to trace a path to this competence without the research that began with anti-submarine warfare and was fostered via wide enough perspectives at the Office of Naval Research that identified and invested in early deep submergence technologies for acoustic research. Collectively the tools, methods and knowledge base that were used to pry open a window into the depths of the ocean to expose enemy submarines revealed other important secrets of the ocean environment, a process that carries on today. As these secrets are exposed one by one

[271] George Rand, "New Solutions Emerge to Solve Old Sonar Problems," *Defense Electronics*, October 1980.

they continue to add to the understanding of the ocean environment, but as was demonstrated earlier, they can and likely will also further complicate security relationships by what they reveal.

Oceanography as a scientific discipline benefited immeasurably from its critical importance to a problem that is first and foremost a security issue. But it also suffered. Although oceanographers did not have an unblemished history of free reign anywhere and everywhere in the oceans, they had enjoyed rather protected status and a general acquiescence to proceed in pursuing their studies for the hundred or so years of their endeavors prior to the full blown involvement of their science in undersea warfare. The security and economic implications that became clear concurrent with the blossoming of the field made it almost inevitable that the "carefree" days of science for science' sake were at an end. The Law of the Sea does not break ocean science as a discipline, but it does considerably constrain aspects of a field that contends with constantly shifting boundaries with respect to the phenomena of interest that are the subject of scientific inquiry. The investigation of physical laws of ocean science must contend with the political laws of men; this is not to be unexpected, but there is an irony when constraint becomes the reward for understanding. A great deal of research is necessary in the oceans to help resolve what may prove to be the greatest challenge to modern man: climate change. When the implications of climate change on security are better understood, it is likely that the oceans will once more become the subject of investigation because of these security concerns. The provisions of the Law of the Sea that advise the conduct marine scientific research may be revised, or may simply be ignored because of the security "loophole" allowed by the exceptions provisions in the treaty. Either way, if historical precedent holds sway, connections between oceanography and security will continue to drive the conduct of oceanographic research for the foreseeable future.

When the relationship between oceanography and security is assessed in the aggregate, the greatest substantive impact upon security that arose from the application of ocean science to undersea warfare and naval operations is not one that might reasonably have been anticipated without an expanded appreciation for the ways in which the natural environment and security intersect. For the myriad of ways that it defines the manner in which ships operate on the high seas, in coastal waters, through strategic straits and chokepoints and with respect to the natural environment, the 1982 United Nations Convention on the Law

of the Sea (UNCLOS III) is without question the most important treaty to affect naval operations on a global scale in history. It seeks to establish compromises between the rights of coastal nations and vessels at sea - whether they are merchants, scientific research ships, or naval warships. The treaty governs international boundaries, the operations of vessels at sea, the harvesting of ocean resources, protections for nations in securing the integrity of coastal waters, and many other concerns related to the use and stewardship of the seas. UNCLOS III provides for an expanded territorial sea beyond the cannon-ball limit, and delimits areas beyond the territorial sea in which coastal states maintain rights for the exploitation of economic resources of the seabed and waters above. Yet it still provides guarantees for unimpeded passage through areas that would fall subsequently under national jurisdictions, but that traditionally or practically represent the most efficient means of ocean passage. New juridical concepts such as archipelagic sea lanes and transit passage entered the lexicon of maritime law to facilitate these accommodations.

The concepts described above are significant compromises: without these types of provisions navies would not be able to operate freely in support of their missions without infringing on coastal state sovereignty or jurisdiction; and in matters of security, maritime powers would not have consented to voluntarily giving up rights that they customarily had enjoyed or that they envisioned as future requirements for maintaining their own security and that of their allies. The Law of the Sea only came into force after the end of the Cold War, so much of the underlying political subtext that existed throughout the treaty's negotiation is no longer of major concern to the parties. The armed naval presence that was such a mainstay of that confrontation has not disappeared from the oceans of the world, but has been dramatically recharacterized from one of bipolarity to a multipolarity that still has not sorted itself out. It is difficult to state with certainty how the provisions of the Law of the Sea will affect maritime security operations, and whether any of the provisions will be wielded politically rather than as direct protections of the principles embodied in the treaty - legitimate concerns over whether the navigational freedoms desired by the United States Navy will be protected.[272]

[272] Alfred P. Rubin, "Monster from the Deep," *The National Interest*, Fall 1994.

Even without signing or adhering formally, the United States recognized most of the Law of the Sea Treaty's norms as customary international practice, and for all intents sought to follow its direction as a matter of operating as part of the international community by respecting the agreement and not acting with impunity in defiance of it. President Reagan said as much at the same time that he announced the United States would not sign the treaty. As a non-signatory, provisions of the treaty that the United States respected were followed as a matter of customary rather than treaty law. Nevertheless, once the U.S. signed the treaty ten years later it "obligated" itself to adhere even more closely - as signing recognized intent to seek domestic ratification as a formal and binding agreement for the nation, and practice needed to be consistent with treaty norms. The political struggle that preceded President Clinton's signing of the treaty, and the debate in Congress before and after – or deliberate lack thereof at times – demonstrated less than unanimous domestic accord, but the last few years have witnessed dramatic changes in the United States position with respect to the Law of the Sea. On November 14, 2001, one of the first actions taken by the U.S. Commission on Ocean Policy that had recently come into being under the Oceans Act of 2000 was the passage of the following terse resolution:

> The National Commission on Ocean Policy unanimously recommends that the United States of America immediately accede to the United Nations Law of the Sea convention. Time is of the essence if the United States is to maintain its leadership role in ocean and coastal activities. Critical national interests are at stake and the United States can only be a full participant in upcoming Convention activities if the country proceeds with accession expeditiously.[273]

Significant in this statement is the fact that the Chairman of the U.S. Committee on Ocean Policy is retired Navy Admiral James D. Watkins, the Chief of Naval Operations almost twenty years earlier under the Reagan Administration at the time President Reagan declined to sign the 1982 Convention. As a member of the Joint Chiefs of Staff and the President's uniformed advisor on naval affairs, Admiral Watkins knew the security implications of the treaty during the tense days of the Cold War. While

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[273] United States Committee on Ocean Policy, *U.S. Commission on Ocean Policy Resolution: United Nations Law of the Sea Convention*, 2001 (accessed March 12, 2005); available from http://www.oceancommission.gov/documents/los_resolution.pdf.

guaranteeing some freedom of movement to the United States Navy, it would also have imperiled others when the United States became subject to all provisions of the treaty – including those associated with tribunals that might become highly politicized by Cold War relationships. One of the few loopholes in the binding nature of the treaty was an opt-out clause that allowed for certain exceptions to be declared for security reasons, but exercising such provisions demonstrates less-than-equal commitment to a "universal" agreement. Declared exemptions may provide legal cover, but they also remove some of the benefit of multilateralism and international comity implied by signing on to the agreement. U.S. credibility of commitment to this treaty will likely hinge on what exceptions if any it stipulates upon ratification or at some point after the treaty is in force as allowed by treaty language. Nevertheless, a move towards ratification represents a significant shift from a policy of steadfast reticence at accommodating national to international interests. Admiral Watkins' leadership of the Oceans Commission and this first declaratory statement issued by that body – although not an official statement of U.S. naval policy - indicate a significant sea change from the views that held sway in the uncertain days of the Cold War.

If the U.S. Commission on Ocean Policy wasted little time after its convening at issuing this forceful resolution, then certainly no moss grew on their recommendation. One week later on November 21st, the United States Representative to the United Nations Economic and Social Council issued the following remarks:

> The United States has long accepted the UN Convention on the Law of the Sea as embodying international law concerning traditional uses of the oceans. The United States played an important role in negotiating the Convention, as well as the 1994 Agreement that remedied the flaws in Part XI of the Convention on deep seabed mining. Because the rules of the Convention meet U.S. national security, economic, and environmental interests, I am pleased to inform you that the Administration of President George W. Bush supports accession of the United States to the Convention.[274]

On February 25, 2004 the Foreign Relations Committee of the United States Senate unanimously voted to send the treaty to the full Senate for advice and consent. There the issue failed to make the calendar for

[274] Browne, *The Law of the Sea Convention and U.S. Policy*, 2.

action by the Senate before the Congress adjourned - something not entirely surprising for a treaty that remained a contentious domestic political issue during an election year. With the opening of the Congressional term in 2005, it remains to be seen whether the Law of the Sea Treaty will reach the Senate Floor for the advice and consent vote needed to ratify the treaty.

The international security state of affairs is once again an important consideration in whether the United States accedes to the Law of the Sea Treaty. The U. S is considered the sole superpower – or "hyperpower" as it was called by a French official – among nations of the world, and the reasons that it projects power around the globe have changed significantly since the Cold War. While it may have the naval and military strength to do so unilaterally, the United States must consider its actions in the context of its overwhelming strength and the way it is perceived by the international community. If it wishes to avoid the "empire" tag that some have sought to attach recently, then adherence to multilateral treaties – or accession in this case – would be favorably received as an indication that the United States does not consider itself above the (international) law. Juxtaposed to the other large international agreement that the United States opposes which most of the remaining countries of the world either embrace (or at least accept despite any misgivings they harbor) – the Kyoto Protocol to United Nations Framework Convention on Climate Change – the Law of the Sea imposes fewer direct restraints on economics and is more in line with norms of international law that the United States already accepts as at least customary if not formal practice – factors that may make it the most politically palatable of the two treaties for domestic politics to address.

With Administration support for the treaty and recognition for the international political capital that would accrue to the United States for acceding even if there are reservations among domestic constituencies, it is possible that the Law of the Sea treaty may receive the advice and consent of the United States Senate required for ratification. Treaties inherently (ideally) reflect the evolution and development of principles of international law and their negotiation reflects changes in international political relationships. At this point in history the world has truly witnessed international change. Perhaps this will

facilitate the universal participation in the treaty envisioned by Ambassador Pardo now more than thirty five years ago.[275]

The catalyst for the Law of the Sea – the potential for exploitation of deep seabed minerals - may be directly linked to the diverse investigations of the oceans in support of security interests in undersea warfare. Although in the end for the lack of success in realizing the golden potential envisioned, this affair may have been much ado about nodules – my apologies – the end result is not. In both scope and participation the Law of the Sea is the most universally inclusive international treaty yet negotiated by the nations of the world – on just about any substantive subject of interest with the possible exception recently of Climate Change. In the direct and indirect ways that the Law of the Sea Treaty affects the national security of maritime nations, and at least the economic security of land-locked nations, it is by a considerable margin the most far-reaching treaty related to security…for it legitimately impacts all nations, and not just a few select military or economic powers.

Political will to tackle this mammoth theme might never have been achieved if not for the investigation of the oceans that occurred in the military context of undersea warfare – particularly at a time that witnessed such a global confrontation as the Cold War. Possibly because of its patrimony of Admiralty Law or as a result of its negotiation during the height of the Cold War, the Law of the Sea Treaty is often narrowly construed as one that governs the operation of merchant and naval fleets rather than one that provides a legal framework for the many other oceanic themes that it addresses. But whether the Law of the Sea Treaty is recognized for its proper scope, or merely for codifying maritime law in its traditional

[275] 148 of the 191 member states of the United Nations have ratified the United Nations Convention on the Law of the Sea as of April 2005, and 121 have ratified the subsequent Agreement Relating to the Implementation of Part XI of the Convention. As a non-ratifying nation, the United States shares the company of Afghanistan, Andorra, Azerbaijan, Belarus, Bhutan, Burundi, Cambodia, Central African Republic, Chad, Colombia, Congo, Democratic People's Republic of Korea, Dominican Republic, Ecuador, El Salvador, Eritrea, Estonia, Ethiopia, Iran, Israel, Kazakhstan, Kyrgyzstan, Lesotho, Liberia, Libyan Arab Jamahiriya, Malawi, Morocco, Niger, Peru, Republic of Moldova, Rwanda, San Marino, Swaziland, Switzerland, Syrian Arab Republic, Tajikistan, Thailand, Timor-Leste, Turkey, Turkmenistan, United Arab Emirates, and Venezuela. United Nations Division for Ocean Affairs and the Law of the Sea, "Status of the United Nations Convention on the Law of the Sea, of the Agreement Relating to the Implementation of Part XI of the Convention and of the Agreement for the Implementation of the Provisions of the Convention Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks," 31 January, 2005 (accessed April 21, 2005); available from http://www.un.org/Depts/los/reference_files/status2005.pdf.

sense, what appears to most escape notice is that the entire affair grew from a very tightly focused problem that existed at the intersection of the environment and security.

ΨΨΨ ΨΨΨ

ΨΨΨ Chapter 3 Safety & Efficiency of Operations at Sea in the 19th Century ΨΨΨ

Every Prospect of an Interesting Cruise

Riding at anchor near the heights of Brooklyn in June of 1831, the 700-ton sloop of war *USS Falmouth* made final preparations for sea. A sloop of war was not a large vessel, only 127 feet in length and just shy of 34 feet at the beam, mounting 16 32-pounder cannons and four 8” 64-pounder shell guns. *Falmouth* had been ordered from New York to sail by way of Cape Horn to Valparaiso, Chile and Callao, Peru to show the flag and demonstrate the resolve of the United States to protect her territorial and commercial interests in the Pacific, not the least of which was a whaling fleet that ranged ever farther into uncharted seas in search of untapped hunting grounds.[1] Aboard the sloop was her recently assigned sailing master, a newly minted Passed Midshipman by the name of Matthew Fontaine Maury. As sailing master, Maury was responsible for the safe navigation of *Falmouth* around treacherous Cape Horn at the southern extreme of South America, and he diligently – but with limited success – sought out information from other vessels on the waterfront that might have assisted in planning a secure voyage.

Maury’s failure to obtain information frustrated his advance planning, but germinated even larger plans whose effects would reach immeasurably further than to ensure the safe passage of this one vessel around Cape Horn. These ideas were to develop as Maury experienced firsthand the challenges of the Cape passage over the coming months.[2] But on a calm moonlit night just before *Falmouth* sailed, voyage preparations were put aside for a moment as the crew received visitors from New York who came to bid them farewell. *Falmouth*’s band entertained her guests after the ship’s officers provided a tour, passing the evening to quadrilles, Spanish dances, and waltzes and striking up the tune <u>Home Sweet Home</u> at the end of the evening as the visitors debarked. “I don’t think it was ever played with greater effect,” later wrote one young woman visitor, “The poor officers seemed to feel every note of it, a three year absence from our

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[1] Howard I. Chapelle, *The History of The American Sailing Navy: The Ships and Their Development* (New York: Bonanza Books, 1949), 350, 358, 517; United States Navy Naval Historical Center, *Dictionary of American Naval Fighting Ships*, (accessed).

[2] Charles L. Lewis, *Matthew Fontaine Maury: Pathfinder of the Seas* (Annapolis: United States Naval Institute, 1927), 24; Frances Leigh Williams, *Matthew Fontaine Maury: Scientist of the Sea* (New Brunswick: Rutgers University Press, 1963), 90-91.

friends and home is no very agreeable anticipation. They have all been to take leave of us, and will probably sail to morrow, for the Pacific. I think they have every prospect of an interesting cruise."[3]

Sailors On the Waves of an Angry Sea

It would be an act of hubris to assert that man has in any way conquered the seas in the modern age; during the epoch of sail it would have been more an act of sacrilege. Seafarers of the day went to sea largely at the mercy of forces beyond their comprehension and whose apparently arbitrary patterns might better have described the whims of some omnipotent deity rather than the regular laws of nature explainable by the scientific investigations of man. This was true under the most everyday experience of winds, currents and tides, but emphatically apparent in the situation of inclement weather. Indeed, even now one is no more likely to encounter an atheist onboard a ship in a fully developed storm at sea than in the soldier's foxhole of the aphorism. Competent at processing only so much of what the senses accumulate into the logic of human understanding, the mind catalogs the rest under acceptance or denial somewhere in the recesses alongside where an individual registers belief or disbelief in a Creator. It is at this threshold of perception and conviction that shipboard observers witness the raw and unimaginable power possessed of an ocean storm.

Comfortable fair weather harmonies created by locally generated wind waves and ocean swells that roll in from afar are disrupted as the energy of the tempest is exchanged between atmosphere and ocean. A rippled sea surface provides frictional toeholds for storm winds to build waves into furious dark walls that advance relentlessly and explode against bulwarks in towering blasts of whitewater. Visibility plummets as the ocean spray is whipped opaque by unremitting gusts, channeled across miles of open fetch to an apparently godforsaken intersection of latitude and longitude. To the roar of the gale is added the unearthly thrum of natural or wire rope shrouds drawn taught and resonating at frequencies unattainable under any other conditions, punctuated by the cracking reports of canvas sail or tarps snapping taut in the gusts. Decks become awash in roiling white and green foam that pours overboard from the scuppers. The subtle

[3] Eliza, Brooklyn, to Joseph A. Constant, Liverpool, June 30, 1831, ALS, Private Collection.

rise and fall of the deck that imparted the muscle memory known as sea legs is replaced by pitching and heaving. Confused seas impose competing strains on structural elements – tension, compression and torsion along the ribs, keel and cross members that are capable of working even the strongest joints.

It is a dance of death for those vessels that ship water and are made less buoyant and responsive to the balancing forces that keep them righted. Sailors pump flood waters to stay afloat, unconsciously battling to stabilize the subtle trigonometry formed of the center of buoyancy, the center of gravity and the induced metacentric height that describes the moment arm responsible for righting the ship as she rolls. The helmsman struggles with the rudder to keep the ship's head into the waves - for going broad side to the seas is akin to an animal submissively laying its throat bare to a stronger foe. The sea knows no mercy for such a gesture, rewarding those who would fight, and conveying those that submit to the cold quiet of the abyss.

> *Onboard the Ship Bainbridge*
> *Latitude 41 Lon 65*
> *28 Sept 1811*
>
> *…the present merely serves to inform you that on the morning of the 22nd instant we encountered the most tremendous gale ever witnessed by any one of about twenty persons on board. We carried away our Main & Fore Mast, and whilst the Ship was on her Beam Ends cut away the Mizzen Mast soon after which she righted. We are now under jury mast making the best of our way home, which I hope we shall reach in 8 or ten days if the winds are any ways favorable. …in our present situation we often make six knots. We unfortunately lost one man over board during the Gale…. Have the goodness to give this information to the persons interested, to whom I cannot write as the Sea is running so high that I can hardly make this intelligible. …*[4]

The passage above was excerpted from an early 19th century letter written by the Captain or Supercargo of a ship on the North Atlantic to inform the Fredericksburg, Virginia merchants who consigned a shipment of spices what befell the vessel and to account for its late – but anticipated safe – arrival. It is likely that the *Bainbridge* encountered another vessel at sea – "spoke" in the language of sail – and this communication was quickly penned so that it might reach the mails when the other vessel made port. There is no telling how many dispatches of this nature were written to explain late arrivals, or how many failed to reach their destination to reveal the fate of ships lost at sea. Unexplained loss of a vessel is a circumstance *almost* unimaginable to mariners today.

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[4] Fontaine Maury, onboard vessel *Bainbridge* at sea, to Masters Murray, Grinnan, and Mundell, Fredericksburg, September 11, 1811, Private Collection.

Modern communications have made just about every square kilometer of the earth's surface accessible by radio or satellite telephone; automatic signaling beacons capable of broadcasting distress codes to initiate search and rescue are standard equipment on many ocean-going vessels and advised of virtually all others that venture offshore. Nothing, however, is completely failsafe. Human error may prevent automatic systems from working as designed, and the vagaries of human judgment can lead to unwise decisions despite the availability of advice or warning. Even if distress eventually is broadcast, depending on the precise location and prevailing weather and sea conditions succor simply may not arrive in time before the righting trigonometry of a vessel is overwhelmed; nevertheless, assisted by EPIRBs (emergency position indicating radio beacons), last known communications, and modern search and salvage equipment, most accounts may be reconstructed forensically if none survive to tell the tale. But where today these are exceptions, a few centuries earlier unexplained disappearances were the norm. Subjected to the whims of winds and seas, vessels of the era of sail were especially vulnerable to damage and debilitation because of the wildly variable duration of ocean passages and the attendant probability of encountering storms or exhausting onboard provisions before reaching port. Aside from the expected rigors and trials of seafaring - and any threats posed by political foes or pirates - mariners of the eighteenth and nineteenth centuries faced two primary challenges: knowing where they were once beyond the sight of land, and getting where they wanted to go as expeditiously as possible to avoid two horrible fates that awaited them if they remained too long at sea: scurvy and starvation, or foundering beyond the reach of notice or assistance.[5]

Two hundred years ago, the most well equipped sailing vessels knew few of the technological amenities common to modern vessels. A ship's state of the art instruments were its compass, log line and hourglass, and either a backstaff, quadrant, octant or sextant for observing celestial bodies (chronometers for determining longitude by the time method were extremely expensive and until the later half of the nineteenth century not carried by the majority of vessels). Hazards were avoided by posting visual

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[5] For a good discussion regarding procedures for addressing emergencies at sea, the reader is directed to John M. Waters, Jr., *A Guide to Small Boat Emergencies* (Annapolis: Naval Institute Press, 1993). For a more thorough review of the dynamics of ship stability, the reader is referred to Allen M. Bissell, E. James Oertel, and Donald J. Livingston, *Shipboard Damage Control*, Fundamentals of Naval Science (Annapolis: Naval Institute Press, 1976).

lookouts and regularly swinging sounding leads; telescopes or long glasses were a ship's long range sensors. Perhaps a thermometer and weather glass or barometer was available if the officers were schooled at divining what the changes in the parameters they measured meant in terms of imminent weather conditions or geographic locale. Visual communication via signal flag (effective in good weather conditions to only a few miles) was the alternative to hailing by megaphone or the unidirectional method of casting off a message in a bottle. State of the art food preservation was achieved either through desiccation or the salting and pickling of provisions, and while spoilage may have been retarded so was edibility. Fresh water was obtained at the discretion of the heavens once reserves carried in barrels became too putrid or ran dry.

Much depended on the ability of the navigator in getting a ship safely to port in short order. Aside from apprenticeships, they learned their craft from treatises such as Moore's - and later Bowditch's - *Practical Navigator* or Maskelyne's *Nautical Almanac and Astronomical Ephemeris*, works that also made available the astronomical tables necessary to reduce celestial observations to corresponding terrestrial positions of latitude and longitude. Where they were available, *Coast Pilots* provided vital information to coasting vessels regarding local conditions and landmarks, but precious little information was available to those navigating the high seas. With his instruments and almanacs – and some luck with clear skies - a skilled navigator could plot the ship's position on a chart and a course he intended to follow to his destination. But at sea the shortest *achievable* distance between two points is rarely a straight line. Sailing vessels needed favorable winds to sail at or close to their compass course, and currents often played havoc with their progress. With respect to these variables, navigators had little to fall back on for advice besides the counsel of their own experience.[6]

[6] Detailed guidance in the use of early marine navigational instruments may be found in contemporary editions of one of the seminal references of the day: Nathaniel Bowditch, *The New American Practical Navigator*, Second ed. (Newburyport: Edmund M. Blunt, 1807). An excellent account of the refinement of the methods to determine longitude may be read in Dava Sobel, *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time* (New York: Penguin Books, 1995). A good general discussion of facets of life at sea in this period may be referred to in the chapter "To Build, to Crew, to Navigate" of Marshall, *Ocean Traders: From the Portuguese Discoveries to the Present Day*.

Modern vessels go to sea with technologies beyond even the fanciful – although in some cases prescient – imaginings of Jules Verne and other fiction writers of the heyday of sail. Global Positioning System (GPS) satellites enable navigators to obtain fixes with accuracies on the order of meters; and although the recently outmoded radio navigation systems such as Omega and Loran achieved poorer resolution, they still provided consistent capability independent of cloud conditions and better accuracy than the tens to hundreds of miles of navigational error common to the days of sail. Satellite relay and direct radio communications permit vessels to maintain virtually continuous contact with shore facilities and other vessels, allowing them to send and receive information in spoken, written, or graphic form and the capability of putting that information to use by means of decision-making computer software. Radar and sonar sensor systems identify other vessels and navigational hazards, even in conditions of near-zero visibility. The rhythmic ping of the fathometer is a constant companion in coastal shallows to warn of shoaling sea bottoms.

Integrated weather observation systems and radio facsimile weather charts provide environmental information that can be used for storm avoidance and for general safe and efficient navigation of the vessel by optimum route selection. Refrigeration and airtight storage allow for a wide range of foodstuffs to be carried without spoilage, and flash distillers and osmotic technologies provide renewable supplies of purified fresh water. And it is easy to overlook the fact that independent propulsion – i.e. not relying solely on wind or other natural forces for motive power – provides the modern mariner with considerable discretion in selecting a route to his destination. Superheater-enhanced high pressure steam boilers, diesel engines, gas turbines, and nuclear power enable ships to maneuver when and where they wish to go at speeds that regularly surpass the fastest sailing vessels ever built. Going to sea is most certainly *not* what it used to be, but the oceans are still a realm to reckon with. With all the technological advancements carried by modern ships and the tactical advantages they provide, vessels of all types and displacements are still at risk before an angry sea.[7]

[7] Comprehensive descriptions of modern navigational aids and instruments, together with information on the availability and use of environmental information is found in the most recent (revised and expanded) edition of the work that has become known by mariners as *Bowditch*: Nathaniel Bowditch, *The American Practical Navigator: 2002 Bicentennial Edition* (Bethesda: National Imagery and Mapping Agency, 2002).

The structure and mechanics of sailing vessels differ from powered craft, but failures in rigging or mechanical breakdown can make vessels of sail or power equally vulnerable before the sea. With stronger materials and improved designs and construction, modern vessels are perhaps more capable than some of their predecessors at weathering ocean storms, but no vessel ever constructed could thwart the worst that nature has to offer. With a storm bearing down on a vessel, it is no act of cowardice to adhere to the best prescription in such a situation: avoidance. Entire fleets are diverted away from storms at sea, or ordered from port well ahead of a storm's arrival to gain the sea room to evade its implacable advance. This is not meant to imply that mariners universally fear that ships cannot survive ocean storms. Loss of vessel may not be anticipated as much as the risk of damage that can run to exorbitant degrees both physically and financially. Expensive communications gear, radars and other sensors inhabit masts and other exposed topside positions. Cargo containers, ships' vehicles, small boats, aircraft, and other equipment are lashed to decks. Blasted by gale or hurricane force winds and battered by broaching seas, any and all of this is vulnerable to damage or to loss overboard.

Taking damage at sea is not an infrequent occurrence despite what might seem an obvious need to prepare for and proceed prudently through rough weather. Time is money for commercial vessels; diversions cut into profit margins. But merchant vessels are not the only ones that weigh safety against monetary risk to stay at sea or divert from their course. In some instances the nature of their assigned mission may force a stay-go decision, but in less constrained situations warships and other government vessels are not impervious to more mundane cost-risk assessments either. The fuel to sortie naval vessels from United States East Coast ports in advance of Atlantic tropical storms can run into the millions of dollars, not to mention the additional expenses that are incurred in terms of man-hours, tug boat assistance, bar and harbor pilot fees and other overhead associated with sending the fleet to sea only to return a few days later when the storm danger has passed.[8] The alternative is to remain in port and hope that winds will not inflict topside damage, nor cause ships to slam against and damage piers or to part mooring lines and collide with other vessels. Risk assessment and forecast skill - even with extensive climatological histories,

[8] Environment News Network, "Navy Scientists Study Ships, Storms," (2001).

data analysis and supercomputer mathematical modeling - do not always augur accurate outcomes…for Mother Nature has yet to prove completely predictable.

With all the advantages of the latest materials, design, and technologies even modern vessels remain vulnerable to the worst that an ocean storm can deliver.

Traversing the Ocean Blindfolded

For centuries, mariners faced the challenge of knowing where they were if they ventured beyond the sight of land. The earliest seafarers were thought mostly to conduct what would be known as a coasting trade, hugging the shoreline and navigating by known landmarks such as headlands or inlets that might aid them in referencing their vessel's position. Not only was this the safest form of navigation, it also afforded the best hope of finding shelter in a storm.[9] As time wore on and seafaring experience grew, it appears that some enterprising mariners took the leap of faith by making a departure from a known shore-based landmark and then striking out in a specific direction to a not-so-distant location beyond the horizon. The latest findings of marine archaeology support this premise, as it appears early trading vessels crossed the Mediterranean and Black Seas rather than strictly hugging the shorelines as they made their way from port to port, but much remains to be learned about these seafarers and the methods they employed to navigate to their destinations.[10] Magnetic compasses in use by the 11th century provided for direction of movement between two points without visual reference and would make such a technique possible. The earliest (extant) charts from the 13th and 14th centuries – known as portolans – support this form of navigation; they offer state of the art depictions of shorelines with cardinal directions drawn like spokes of a wheel from the various ports on the chart to indicate the compass direction of travel to another port.[11] This is not an unreasonable attempt over short distances provided that winds or currents do not conspire to displace the

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[9] Excellent accounts of the evolution of the art and science of navigation are found in Per Collinder, *A History of Marine Navigation* (London: B.T. Batsford, Ltd., 1954); Hewson, *A History of the Practice of Navigation*.
[10] Ballard, *The Eternal Darkness;* Robert D. Ballard and Malcolm McConnell, *Explorations: My Quest for Adventure and Discovery Under the Sea* (New York: Hyperion, 1995).
[11] Stephanie Faul, *Portolan*, 2000 (accessed April 12, 2002); available from http://mappa.mundi.net/locus/locus_003/; Howse and Sanderson, *The Sea Chart*, 9-13.

mariner from his expected route of travel, because little means were available to confirm a ship's position on the open sea and danger was often only a few compass points off a safe track – the *Scylla* and *Charibdis* allegory was more than a baseless myth.

Astronomy and mathematics solved the georeference problem at sea along a north-south axis; latitude was determined by measuring the height of the sun on the horizon at its highest point of passage, and was a well-known skill of navigators of the 15th century. But the equally vital determination of longitude at sea was not perfected until the middle of the 18th century; it was *possible* earlier than this by skilled navigators using a complicated set of celestial calculations and the proper astronomical almanacs, but to the less learned mariner it remained largely guesswork. Precise time was the key and engineering was required to make this next leap of longitudinal progress, in the form of springs, gears, and levers of precise chronometers, for the more traditional pendulum clocks were useless on the pitching deck of a ship.[12]

Chronometers sturdy enough to withstand the rigors of sea travel while still accurately telling the time of day at the Royal Observatory in Greenwich England (the longitude of which marked the north-south circumferential reference of the globe) enabled navigators to compare Greenwich Time with local time at their position. If a different longitudinal reference was used – often the case for mariners of various nationalities - corrections could be made based on the known difference in longitude between the alternate reference and the Greenwich Meridian. On a 360-degree globe, 24 hours of the solar day divided the peripheral arc into 15-degree segments for each hour of the sun's passage around the Earth. Determining the number of hours ahead of or behind Greenwich Time (by observing the moment of solar noon – the highest passage of the sun over his latitude – and then checking the chronometer to compare the time of that event with Greenwich Time), the navigator was able to accurately estimate his longitude.[13] But fixing

[12] Norman J. Thrower, "When Mapping Became a Science" in *UNESCO Courier*, June, 1991 (accessed February 2, 2002); available from http://www.arts.uwa.edu.au/History/mapping_conquest/5_W. A comprehensive account of the competition to produce a reliable and seaworthy chronometer is chronicled in Sobel, *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time*.
[13] Bowditch, *The American Practical Navigator: 2002 Bicentennial Edition*, 1-9; P.V.H. Weems, "Navigation" in *Encyclopedia Britannica*, 2000 (accessed February 3, 2002); available from http://search.ebi.eb.com/ebi/article/0,6101,35939,00.html.

one's position was only part of the many tasks of a successful voyage. To reach his destination, the navigator had to contend with winds and seas that determined the progress his vessel made enroute.

To the uninitiated, the ocean beyond the sight of land appears a trackless place, blue stretched upon blue merging imperceptibly into a blue-gray horizon, spotted here and there by the white-foam flecked crests of waves. Featureless as it may appear, the ocean is far from some vast, impartial and homogenous body of water indifferent to the attempts of seagoing vessels to make way upon its surface. It is instead dynamic, and if there is a constant it is motion; and the sea moves - whether the eye detects it or not - horizontally as well as vertically at each point of its imperfectly measurable volume. Through the stress of winds that gain traction in many tiny wavelets until they are able to induce motion over vast sheets of the surface waters; because of density differences based upon temperature and salinity; and under the influence of large planetary and celestial forces that induce broad movements in large bodies of water, the oceans remain constantly in motion.

An understanding of currents was not unfamiliar to mariners who often sailed from ports in rivers a fair distance from the sea, and to coasters whose knowledge of inshore currents was considered essential to piloting skills, but the notion that discrete currents existed in the oceans that might assist or impede a voyage was not quite so straightforward.[14] Sailing ships, most characterized by broad hulls in order to carry cargo and provisions on lengthy voyages, could only make a few knots speed even with their sails full. Five knots was considered good progress and often annotated in the ship's log to indicate particularly favorable conditions.[15] But strong open-ocean currents such as the Gulf Stream off the Atlantic coast of the United States could also run three to five knots. A ship attempting to stem the Gulf Stream on its way to America could be effectively becalmed even with its sails full, making little westward progress for days at a time.

[14] Jean Lee Latham, *Trail Blazer of the Seas* (Cambridge: The Riverside Press, 1956), 52; Elbert S. Maloney, *Dutton's Navigation and Piloting*, 14th ed. (Annapolis: Naval Institute Press, 1985), 1-4.
[15] Carl C. Cutler, *Greyhounds of the Sea* (New York: Halcyon House, 1930), 53.

The experience of *Bainbridge* likely illustrates this phenomenon. Laden with spices, the ship sailed from Portugal for New York, probably along a track just south of 40 degrees North latitude - along which both Lisbon and the Azores (a common stopover) are located. As it happens, this band of latitude is characterized by strong prevailing westerly winds - headwinds for an American-bound ship. The time of year is also midway through the Atlantic Hurricane Season, at a point when storms still veer far enough to the East to boresight this travel lane.[16] If the Captain had decided instead to sail south to avail himself of the northeast trade winds in crossing the Atlantic, and to approach New York from a southeasterly heading up the East Coast of the United States, it is unlikely that he would have been at North 41 degrees latitude while still east of New York at West 65 degrees longitude - unless in its injured state, *Bainbridge* was strongly set northeast by the flow of the Gulf Stream. The ship's reported position on the 28th of September placed it about 300 nautical miles east of New York. If the writer did not send the letter with a passing vessel but rather mailed it in a timely manner when he reached port (it is postmarked October 8th), then it took some ten days for *Bainbridge* to cover 300 nautical miles, a remarkably adept estimation on his part at the time of writing. A distance of 300 nautical miles covered in roughly 240 hours equates to a speed made good over ground of 1.25 knots (where speed made good over ground does not equal speed through the water because of offsetting currents, and some element of liberality is acceptable in this estimation considering that time lost to anchoring, etc. deflates this approximation of speed). If *Bainbridge* made it to New York in eight days and the writer tarried a few days in posting his letter, the ship still made good roughly 1.6 knots on her journey! Assuming that the writer's claim of 'often' making six knots was accurate, *Bainbridge* was most likely stemming the Gulf Stream. To his credit, the writer *appears* to have recognized this and allowed for delay.

Antwarp, Dec 16th 1845

> *The Talina is now in the Stream and will proceed down the river tomorrow… The weather now looks better and I hope I will be able to get out as soon as I get down. If I had being ready before I could not have gone to sea. The weather has being very bad. The ship Trenton of Bath has being down at Flushing the last five weeks. Bound out. And is still there, with the loss of an anchor. I hope and pray the Talina will get out when she gets down for I'm Sick Sick of Antwarp.*[17]

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[16] On a transatlantic crossing 186 years later in early October 1997 the author encountered both hurricanes and tropical storms during a very active season…although this was experienced in a vessel of 44,000 tons as compared to *Bainbridge*, which in all likelihood displaced a good deal less than 1,000 tons.

[17] Edward Collins, Antwerp, to Masters Magoun and Son, Boston, December 16, 1845, ALS, Private Collection.

The Captain of the *Talina* was writing a routine report to his employers at Boston to let them know that he had on board $36,000 dollars to buy spices, and that he hoped he could complete a round trip to the Spice Islands in ten months. But what is immediately evident from the excerpt is his utter helplessness – as well as that of the Captain of the vessel *Trenton* – before prevailing environmental conditions. If the winds were favorable, *Talina* would put to sea upon reaching Flushing; if not she faced an uncertain wait. To be sure this account is anecdotal; perhaps even with the best environmental information possible and a valid forecast, *Talina* would still have needed to 'drop the hook' and wait for a combination of favorable winds and tides. It is not meant to imply that these mariners were totally ignorant of their prospects of getting to sea or making headway. Onboard *Bainbridge* the writer was able to make a reasoned estimation of his arrival in New York (this is not totally unexpected considering he may have simply extrapolated the present conditions he faced a relatively short distance from his destination in waters well-traveled by American sailors) with one very important caveat: "*…if the winds are any ways favorable.*"

Notwithstanding the writer's apparent comprehension of the situation at the time he dashed off his letter to the Fredericksburg owners of his cargo of spices, it is questionable whether *Bainbridge* would have risked such a perilous voyage - or would have done so along the same track in the face of persistent headwinds - had the person responsible for voyage planning known about the probability of encountering such a destructive gale. For a sailing vessel, the less time at sea in such a situation the better. A shorter route as the crow flies is not necessarily faster – or safer – than one longer in sea miles that leverages natural forces and avoids probable obstacles – hindsight it appears at least for some time to come.

Rio Janeiro, Brasil, S.A.
Aug. 19, 1849.

…when in latitude about thirty-four or five, about opposite the mouth of the river La Plata…we encountered a very heavy storm...it was a fearful storm, rolling and dashing and throwing the ships about in a frightful manner. But on Sunday night, in the after part, the storm abated. … Tuesday night we had another storm upon us more furious than the first. …we had but little more good weather until Friday, when at night a storm heavier than either of the others gathered upon us, and after being tossed about in the cabin, or rather in our berths, in an awful manner till morning, I went on deck and found we were scudding out directly off our course almost without any sail at the rate of ten knots (miles) an hour. All day the ship scudded off towards Africa and all the night and nearly all the next day. In the heavy gale of Friday night the ship was found to be unmanageable and now away we were speeding before the wind ten knots an hour for nearly two days, directly off our course. …the captain…concluded to go to California by way of Cape Good Hope…and though immensely farther, it could probably be accomplished nearly as soon as by Cape Horn, and in fact, in the present state of the vessel it could not double that stormy Cape. But most of the passengers were very much dissatisfied at changing the course, so the captain concluded to come back to this port, (Rio Janeiro), to prepare the ship anew for the terrible passage of Cape Horn. …now we had to turn

back and go seventeen hundred and fifty miles over the same stormy sea which we had come. And then…would have to come to this point seventeen hundred miles again. …I have been to sea before, but never experienced anything like we have this voyage. I should by no means have thought of coming this way if I had any idea of the severity of the passage. Nor are we certain that we are yet through the worst of it. …we have sailed thirty-five hundred miles and through an almost constant succession of dreadful storms, and now here we are, just where we started from. …Eight or nine thousand miles from Cape Horn, you know but little of its storms. When we were here before, there were two vessels here which had been wrecked at the cape and had come back to repair damages – there are now five or six which have come back in the same situation since we left. And we learn here that there are seventeen vessels at Montevideo which have come back from Cape Horn to repair damages. …What will be our doom we cannot tell. But God is our protector, and if our trust is truly in Him we may know that all will be finally well. …It is now ninety-two days since we got on board the ship in New York. We have sailed ten thousand miles and we have twelve thousand miles yet to go, and the worst part of the voyage yet to accomplish.[18]

What is plain from these accounts and true generally is that captains went to sea and tried to *overcome* circumstances they faced as a matter of course. Generally ignorant of prevailing environmental conditions unless they often sailed a given route, navigators might attempt to stem currents or beat into winds for weeks (months even, in particularly treacherous passages such as that from east to west around Cape Horn) to little or no avail; in their own words it was not uncommon to "beat [their] head three times against a billow and then fall off and sail around it."[19] Repeatedly stymied by currents they didn't know existed in what appeared to be a pathless ocean, with respect to the physical properties of the seas in which they sailed they were as one captain described it, "traversing the ocean blindfolded."[20] They knew only the rudiments of finessing the prevailing winds and currents to bend them to their intent. Other than a broad knowledge of the Trade Winds – that were certainly of benefit but by no means 'gospel' - and the existence of the current that Benjamin Franklin had named the Gulf Stream, mariners had little to go on other than their own experience, that of their shipmates, and what knowledge they may have wrested individually from other seafarers.[21]

With their knowledge at only this level of granularity mariners often sailed hundreds of miles from what may have proved a more advantageous route to get to the Trades, sail with (or avoid) the Gulf Stream, or

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[18] James Woods, "Perils of a California Voyager," *The Barre Patriot*, October 12, 1849, 2.
[19] Cutler, *Greyhounds of the Sea*, 53.
[20] Matthew Fontaine Maury, *The Physical Geography of the Sea*, Fifth ed. (New York: Harper & Brothers, Publishers, 1856), 287. Similar sentiments about sailing 'blindfolded' prior to the use of Maury's charts and advice were also expressed by other captains and may be found in: Matthew Fontaine Maury, *Maury's Sailing Directions*, Eighth ed., II vols., vol. II (Washington: Cornelius Wendell, Printer, 1859), 199.
[21] International Marine Educators Inc., *The History of Navigation*, July 12, 1999 (accessed April 12, 2002); available from http://boatsafe.com/kids/navigation.htm; Weems, (accessed).

follow the ‘proven’ tracks of their ancestors – inefficiencies that took time (read: money) and made them vulnerable for greater periods to storms at sea. Voyages by the same ship between the same ports, or by sister ships sailing at the same time between the same locations could differ by weeks at a time.[22] Able to fix their positions by the sun and stars (weather permitting), and later in the era by the chronometer if one could afford it to better resolve longitude, competent mariners knew generally *where* they were. Using portolans and charts of coastlines made by those who went before them together with a compass, they could determine a course to sail and estimate the distance to their destination. But without knowing the winds they would face along the way, or the currents that might set them from their intended course, they had little accurate feel for *when* they might get there. Knowledge passed down that might have assisted in making these transits was closely guarded as state or corporate secrets, but even this knowledge imparted conflicting guidance and was shrouded by myths and superstitions.[23]

Although the anecdotes above recount the experiences of two merchant vessels, the sea did not – and does not – differentiate between merchants and warships in how it behaves with respect to them. The Spanish Armada of 1588 (and a subsequent expedition in 1589) failed in its assault on England as a result of unfavorable winds and seas as much as an effective defense mounted by the Royal Navy.[24] The British understood how critical environmental conditions were in the battle; the motto on the victory medal read “Flavit Deus, et dissipati sunt” – “The Lord sent His wind and scattered them.”[25] The Japanese term ‘kamikaze’ originated not with the last ditch efforts during World War II to launch suicide aerial attacks, but rather refers to the earlier ‘Divine Wind’ that twice sank Mongol invading fleets in the 13th century.[26] From a tactical point of view, the upwind position – or ‘weather gauge’ – was the position that controlled

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[22] Maury, *Maury's Sailing Directions*. Numerous tables record the duration of voyages between ports by different vessels, and in some cases the same vessel on separate voyages.
[23] Ruth Brindze, *Charting the Oceans* (New York: The Vanguard Press, Inc., 1972), 1-12.
[24] National Maritime Museum, *The Spanish Armada*, (accessed January 13, 2005); available from http://www.nmm.ac.uk/server/show/conWebDoc.171.
[25] William Oliver Stevens and Alan Westcott, *A History of Sea Power* (New York: Doubleday, Doran & Company, Inc., 1920), 163.
[26] William Kirsch, *The Divine Wind: A Study of the Mongol Invasions of Japan*, (accessed January 13, 2005); available from http://danielroy.tripod.com/cgi-bin/alternate/mongolia/opi2.html.

the pace of the battle during the Age of Sail and determined the naval doctrine that was strictly adhered to by captains of ships of the line.[27]

Winds and seas were – and still are – critical to naval operations, both in evident as well as less-than-obvious ways. But at the level of the individual vessel, the manner in which winds and seas affect ships on a daily basis has always been irrespective of merchant or military classification. The imagery of the gale setting *Bainbridge* on her beam ends as described in the letter quoted earlier, a death roll from which sailing ships often failed to recover, allows a glimpse of the challenges of early 19th century seagoing travel experienced by all classes of sailing vessels - dangers that ships were more likely to experience the longer they remained at sea. Professional naval officers differed little from civilian mariners in that they too learned their trade as apprentices – midshipman – from the officers who trained them, and they sailed with the passed down knowledge and oral traditions with their attendant myths and superstitions of the sea, and a reluctance to deviate from what they knew. Going to sea was risky business as it was; few would hazard departures from accepted routes to venture on some unproven one in the hopes that it might prove a more efficient or potentially safer track – better the devil you knew… Not until the middle of the 19th century would this form of ignorance begin to wear away; at that time information about the ocean environment began to be gathered systematically and scientifically, and shared so that all boats were lifted by the rising tide of knowledge.

A New Science

There is some level of disagreement over the origin of oceanography as a scientific discipline. It is often stated that the dispatch of the British *Challenger* Expedition in the 1870s was the beginning of the modern science because the primary (stated) mission of the voyage was to gather oceanographic information – as opposed to a voyage of exploration or other purpose that merely gathered environmental information as a matter of course and secondary to the primary intent of the undertaking. Some consider the work of the early 19th century British explorer James Clark Ross as the first example of deliberate

[27] A. T. Mahan, *The Influence of Sea Power Upon History*, Twelfth ed. (Boston: Little, Brown and Company, 1943), 5-6.

oceanographic inquiry since his arctic expeditions had such an environmental context. Still others cite the famous explorations of Captain James Cook in the latter half of the 18th century when the volume of environmental information gathered as part of these epic voyages is weighed against other contemporary ocean related data that might be deemed oceanographic.[28] But with these expeditions and earlier ventures, it must be asked whether the nature of their scientific inquiry merely constituted investigations that took place *on* the oceans rather than *of* the oceans. The first voyage undertaken (and recorded) in a ship configured primarily for scientific discovery was a British expedition led by Edmond Halley in 1698 in *Paramore*. Halley's experiments with magnetic variation were not of an oceanographic nature, but he hoped that his work would have some practical application to navigation. A voyage possessing some marine scientific component did not take place until 1773, when two British vessels under the command of Captain C.J. Phipps, H.M. Ships *Racehorse* and *Carcass* were dispatched in an attempt to reach the North Pole. Along the way they successfully conducted a deep-sea sounding and measured deep-sea temperatures. Even though they failed to penetrate the ice as far as the pole, the British were lucky their attempts avoided greater misfortune…one member of the expedition made a "narrow escape" on the ice from a polar bear – a junior officer named Horatio Nelson.[29]

Without seeking to denigrate the contributions of any of these endeavors, there is an alternative – one that predates the *Challenger* Expedition by decades and that differs from the body of work compiled by Cook and Ross, or Halley and Phipps in both intent and scope. This effort, initiated by the American naval officer Mathew Fontaine Maury, was so fundamentally different that perhaps the pre-eminent natural scientist of the day - the Baron Alexander von Humboldt – publicly congratulated Maury on his founding of a new science: the *physical geography of the sea*.[30] Maury's program of coordinated observation, recording, collation, and interpretation of oceanographic data was an outgrowth of his experience at sea. He recognized that the relative ignorance of seafarers regarding the environment in which they operated

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[28] William Herdman, *Founders of Oceanography and Their Work: An Introduction to the Science of the Sea* (London: Edward Arnold & Company, 1923); Ian Jones and Joyce Jones, *Oceanography in the Days of Sail* (Sydney: Hale & Iremonger, 1992); Schlee, *The Edge of an Unfamiliar World: A History of Oceanography*.
[29] Rice, *British Oceanographic Vessels 1800-1950*, 1.
[30] Maury, *The Physical Geography of the Sea*, xiii; John W. Wayland, *The Pathfinder of the Seas: The Life of Matthew Fontaine Maury* (Richmond: Garrett & Massie, Inc., 1930), 92.

might be rectified by the sharing of hard-won experience and the subsequent deliberate expansion of that knowledge base for the ultimate benefit of all who went to sea.[31] Although the credit for being first in the field might be in dispute, what is of immediate – if oft overlooked – notice is that all of these candidate ventures were military ones.

Fourteen years after his uncle Fontaine wrote about the near-sinking of *Bainbridge* in a brutal Atlantic storm, Matthew Fontaine Maury reported for duty as a Midshipman in the United States Navy, having attained his appointment via the offices of Congressman Sam Houston. Although he was born in central Virginia and grew up on a farm far from the ocean in Tennessee, he was not unfamiliar with the naval service. Maury's older brother John had an illustrious career in the Navy during which he had been marooned for a few years on a Pacific island; rescued by Commodore David Porter in the frigate *Essex* and subsequently fought in that ship's ill-fated and outgunned battle with the British ships *Phoebe* and *Cherub* at Valparaiso during the War of 1812; and before succumbing to yellow fever in 1823, was Flag Captain of the West Indies Squadron that succeeded in suppressing piracy in those islands.[32] Midshipman Maury's first duty was onboard the newly launched frigate *USS Brandywine*, and that ship's inaugural task was to transport the Marquis de Lafayette home to France following his 1824-1825 farewell visit to the United States.

An eager student, Maury sought to put all of his available time to studying his newfound profession, an endeavor both admirable and practical as all midshipmen were required to appear before an examining board after a trial period of six years sea duty in order to be continued in the naval service. Attempting to master the concepts of spherical trigonometry, he resorted to the rather unorthodox method of chalking problems on cannon balls so that he might study as he passed the time on deck watch. Apparently inspired by *Brandywine*'s honored guest, Maury appropriated Lafayette's famous answer when questioned why he came to fight in the American Revolution - "*Cur Non* (W*hy Not)?*" - as a rejoinder to questions about his

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[31] Maury, *The Physical Geography of the Sea*, v-vii.
[32] Chester G. Hearn, *Tracks in the Sea: Matthew Fontaine Maury and the Mapping of the Oceans* (Camden: International Marine, 2002), 27-31; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 22-25, 30.

motives and techniques. Joined to an already inquisitive personality, the sentiment would serve to bolster Maury when later ideas and theories were considered by others to be even more unorthodox.[33]

After its initial cruise to France and the Mediterranean, *Brandywine* returned to the United States for refit, and Maury subsequently made his first journey around Cape Horn in late 1826 when that vessel joined the Pacific Squadron at Callao, Peru. In March of 1827 Maury transferred to another vessel of the Pacific Squadron, the sloop of war *USS Vincennes* which continued on station patrolling the west coast of South America for the next two years. In 1829, *Vincennes* was ordered back to the United States, but this time traveled westward instead of returning east by way of Cape Horn, and completed the first circumnavigation of the globe by a U.S. vessel. In the process, Maury was able to visit many sites in the Pacific that would prove significant to U.S. interests including the Marquesas Islands, an important replenishing stop for American whalers that plied the warm waters of the central Pacific in search of sperm whales. On this voyage *Vincennes* also stopped at the Hawaiian Islands, the Philippines, and the port of Macao in China. From Macao Maury was able to make the trip to visit the restricted trade area of Canton seventy miles up the Pearl River, the only port through which trade with the West was authorized by the Chinese government. His experiences formed impressions of the importance of these locations to U.S. commercial interests, and provided perspective on the vast distances that had to be covered by vessels plying routes between Pacific ports.[34]

Upon returning to the United States, Maury was successful in the first of his two allotted tries at the midshipman's examination - a tiresome affair that tested the midshipman's grasp of navigation, mathematics, foreign language, philosophy, and seamanship - and was made a Passed Midshipman in June 1831. He was immediately ordered as sailing master of the sloop-of-war *Falmouth*, which was scheduled to make a cruise around Cape Horn to join the Pacific Squadron. Having experienced the dangerous passage once before, Maury determined that his voyage as navigator would prove a safe and expeditious one. Before sailing he scoured the waterfront of New York for information on conditions that he could

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[33] Latham, *Trail Blazer of the Seas*, 35-36; Frances Leigh Williams, *Ocean Pathfinder: A Biography of Matthew Fontaine Maury* (New York: Harcourt, Brace, & World, Inc., 1966), 39-40.
[34] Lewis, *Matthew Fontaine Maury: Pathfinder of the Seas*, 13-19; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 59-83.

expect enroute, or other tips that might assist him in navigating the *Falmouth* on her journey. Captains familiar with the route offered him little help. The knowledge was considered 'trade secrets' and was not freely offered for use by the Navy, or in any fashion that other sailing vessels might use for the fear of eroding the advantage that experience brought to successful captains in winning cargos. After diligently searching for information he had thought would have been freely available because of the number of Navy vessels and merchants that plied the route, he failed to secure the information he sought on winds and currents.[35]

Sailing south along the coast of South America, bound for Rio de Janeiro on the first leg of the journey, Maury meticulously kept notes on the type of information that had been denied him prior to his departure: winds, weather, the set (direction) and velocity of currents, astronomical variations, and the deviation of the compass. He noted coastal features and compared his charts with what he encountered along the way to determine inaccuracies (that abounded in those days); the young United States Navy relied on charts it purchased commercially and from foreign governments and had little to say about their updating or quality control.[36] Rounding Cape Horn, *Falmouth* fell in with a British vessel, *Volage*, also making the passage and in company the two vessels sailed into the teeth of a Westerly gale. As sailing master the recommendation on how to proceed rested with Maury; he made the unusual decision to fall off south and *Falmouth* found favorable easterly winds past 60 degrees South latitude. Sealers Maury had met in Rio that hunted by the South Shetland Islands had told him that winds blew from the east near the ice that bordered (what later turned out to be) the Antarctic continent.[37] He decided to avail of their experience as few other vessels ever ventured (intentionally) that far south of the Cape in making the passage, and Maury had garnered no intelligence from any that might have! *Volage* persisted on the inshore passage and was driven back eastward; *Falmouth* succeeded in doubling the Cape and reached Valparaiso, Chile in good order. *Volage* doggedly attempted to gain the inshore passage twice more before succeeding and had to

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[35] Lewis, *Matthew Fontaine Maury: Pathfinder of the Seas*, 24; Schlee, *The Edge of an Unfamiliar World: A History of Oceanography*, 36-37; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 90-91.
[36] Lewis, *Matthew Fontaine Maury: Pathfinder of the Seas*, 92.
[37] Janice J. Beaty, *Seeker of Seaways: A Life of Matthew Fontaine Maury, Pioneer Oceanographer* (New York: Pantheon Books, 1963), 54.

immediately put in for repairs for damage inflicted during her three hard fought attempts to double the Horn.[38]

Gathering accounts from those navigators among the Pacific Squadron that he did find willing to share their experiences, Maury began the first of his literary efforts at changing the way information was passed among seafarers. Studying his own notes and the information he pried from others, he determined that during passages around Cape Horn vessels experienced westerly winds three times as often as they saw easterly winds. Maury concluded that the inshore passage, which was the shorter route, was preferable *under the right wind conditions* (easterly winds). But he noted that "good passages are more frequently made by those vessels, which finding contrary gales off the Cape, stand boldly to the south, than by those that lie to in them, keeping near the parallel of the Cape."[39] He wrote his findings down as methodically as possible, supported by the facts he meticulously gathered, and mailed them to an academic journal in the United States. Maury's first published effort, "On the Navigation of Cape Horn," appeared in the *American Journal of Science and Arts* in June 1834.[40] Transferring from *Falmouth* to the schooner *Dolphin* and later to the frigate *Potomac* within the Pacific Squadron, Maury sailed in that vessel for the United States in February 1834. After an eastward passage of Cape Horn, *Potomac* encountered a dangerous field of icebergs near the Falkland Islands and was damaged by a collision with one in a thick fog, further impressing upon Maury the dangers that mariners faced along even well traveled routes. After repairs in Rio, *Potomac* departed and returned Maury to New York one month before his first article was published.[41]

As was often the case for officers in the small peacetime United States Navy, Maury was placed on extended leave after his return to the United States in May of 1834. Seagoing billets were limited and officers competing for promotions had to bide their time ashore awaiting career enhancing assignments at sea. Maury determined to make the most of his time and worked dedicatedly at completing a work that he felt had been required since his days as a midshipman chalking spherical trigonometry problems on cannon

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[38] Ibid., 55-56; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 92.
[39] Quoted in Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 93.
[40] Hildegarde Hawthorne, *Matthew Fontaine Maury: Trail Maker of the Seas* (New York: Longmans, Greene and Company, Inc., 1943), 49.
[41] Wayland, *The Pathfinder of the Seas: The Life of Matthew Fontaine Maury*, 37.

balls: a consolidated text that included the requisite math, science, and astronomy required to teach young officers about navigation. Sailing ships and naval vessels had long carried *The American Practical Navigator*, Nathaniel Bowditch's signature work. However *Bowditch* - as it was known – did not endeavor to teach the novice, but rather was written to serve the practiced navigator and lacked the theoretical underpinnings that made navigation more than an exercise by rote. Maury had pined away at the lack of formal training afforded midshipmen at sea and sought to fill the gap that existed between the practical experience gained walking the deck, and academic pursuits that received little attention yet provided the theoretical basis on which the profession depended.[42] While he did not expect to profit by sales of his text, he thought it might, "be of some collateral advantage in making my name known to the [Navy] department and to my brother officers in a favorable manner."[43]

Maury's work, *A New Theoretical and Practical Treatise on Navigation*, created quite an impression in the Navy. At first officers were surprised that such a work could have been produced by a Passed Midshipman, but favorable reviews soon circulated within the service. A Navy Captain (then the Service's highest rank) remarked that, "It illustrates with clearness and simplicity the principles on which navigation is founded," and another senior officer described it as "far superior as a book of instruction" to Bowditch's *American Practical Navigator*.[44] Bowditch himself acknowledged the worth of Maury's contribution beyond what his own work had provided. In the *Southern Literary Messenger* a review by Edgar Allen Poe noted, "The Spirit of literary improvement has been awakened among the officers of our gallant Navy. We are pleased to see that science is also gaining votaries from its rank. Hitherto, how little have they improved the golden opportunities of knowledge which their distant voyages held forth and how little have they enjoyed the rich banquet which nature spreads for them in every clime they visit!"[45] Such reviews brought Maury's work celebrity, and it eventually became the training text for the seagoing United States Navy as well as that of the Naval Academy when it was founded at Annapolis a decade later (in no small part due to Maury's own lobbying efforts).[46] Near his name on the title page, Maury answered any

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[42] Lewis, *Matthew Fontaine Maury: Pathfinder of the Seas*, 26-28.
[43] Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 103.
[44] Ibid., 109.
[45] Quoted in Lewis, *Matthew Fontaine Maury: Pathfinder of the Seas*, 28.
[46] Wayland, *The Pathfinder of the Seas: The Life of Matthew Fontaine Maury*, 40.

questions about his motivation or qualifications to produce such a work with the pithy statement: "*Cur non*?"[47]

The Track Not Taken

Matthew Fontaine Maury made a name for himself, a name that soon after publication of his *Treatise on Navigation* appeared on the Lieutenant's List. But rank held sway in the Navy, and though Maury was a Lieutenant, he was a junior one. After a disappointing sequence of events prevented him from joining the U.S. Navy's Exploring Expedition to the South Sea, the only sea duty available to him was work conducting coastal surveys of the Carolinas. In 1839, a freak stagecoach accident lamed Maury enroute from a visit to his family in Tennessee to New York where he was to join his ship for one of these assignments. He was thrown from the coach when it overturned, broke his leg and severely damaged his knee. A botched set by a local doctor left him without full range of motion in his leg. After a long period of recovery, during which he repeatedly sought to return to sea duty to no avail, he was assigned to the Depot of Charts and Instruments where his skills and knowledge might best serve the Navy.[48] In addition to its role as a depository for nautical charts (at that time charts were largely produced by the Royal Navy and in short supply), the Depot was a clearinghouse for valuable instruments such as compasses, sextants, barometers and chronometers that were removed from vessels during times of upkeep, refurbished and calibrated, and subsequently sent to sea on other vessels that needed them. The Depot also served as the depository for logbooks from all ships of the United States Navy since its beginnings a half-century earlier.[49]

Surrounded by stacks of logbooks that he found in various stages of disrepair, Maury was struck by the vast wealth of knowledge they contained. Primarily records of ships' positions in the course of their voyages, many of the logs also contained annotations about winds, waves, weather, and currents that aided or impeded the vessels' progress…keen observations jotted down by veteran seamen who had cumulatively

[47] Lewis, *Matthew Fontaine Maury: Pathfinder of the Seas*, 28.
[48] Miles P. DuVal, Jr., *Matthew Fontaine Maury: Benefactor of Mankind* (Washington: Naval Historical Foundation, 1971), 10-11; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 113-124.
[49] Williams, *Ocean Pathfinder: A Biography of Matthew Fontaine Maury*, 105-110.

served hundreds of years at sea. Recalling his own efforts prior to leaving port on *Falmouth* to learn about conditions that might be encountered on the voyage to the Pacific, and the dearth of information made available to him, and knowing that his "*On the Navigation of Cape Horn*" had been generally well received, Lieutenant Maury developed a plan. Though men had sailed for centuries, little had been recorded about the voyages they made outside the notes in logs such as those he had in his custody at the Depot. As Maury had learned when Sailing Master of *Falmouth*, what precious little information that was circulated among seafarers passed by word of mouth and then was guarded by those who possessed it, the key to their livelihood and reputation as skippers that could successfully haul precious cargoes in the international trade. What if this tradition could be turned on its ear? What if in the process centuries of myths and legends of the sea could be dispelled - proved false with empirical evidence? 'Book learning' was frowned upon in a profession that prided itself on deck experience and Maury was sure to come under fire for directing seafarers in the course of their travels all around the world from his small office in Washington. But if Maury merely collated information that represented the observations and impressions of many experienced mariners (and annotated it as such)… Information from a single source of experience – Maury's own - might be refuted, but information gleaned from logs as recorded by many sailing masters unbiased to Maury's plan could hardly be impugned.[50]

If the wisdom of one old salt on the waterfront that was familiar with an ocean route was invaluable to a navigator with no other source of reference, what did the observations and wisdom of ten mean? One hundred? One thousand? What did the collective wisdom of thousands of sea captains plying many ocean routes at different times of the year and different conditions of winds and sea mean to both peers and novice seamen alike? Maury envisioned a plan that opened the seas to a wider cadre of mariners who would benefit from the experience of those that preceded them, a scheme that would allow them to sail more quickly – and safely – in ever expanding routes of international trade and travel. As new routes were blazed and old ones traveled anew, further data points would be added to the growing storehouse of knowledge. More data would provide better resolution of prevailing conditions and conclusions regarding

[50] Beaty, *Seeker of Seaways: A Life of Matthew Fontaine Maury, Pioneer Oceanographer*, 98-100; DuVal, *Matthew Fontaine Maury: Benefactor of Mankind*, 14-16; Hawthorne, *Matthew Fontaine Maury: Trail Maker of the Seas*, 82-87; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 144-157; Williams, *Ocean Pathfinder: A Biography of Matthew Fontaine Maury*, 112-121.

optimum routes of travel at various times of the year. From this collection of data, it was possible that even larger patterns might emerge over regions more broad than just the well-traveled sailing lanes, patterns that might allow captains to avoid dangers and achieve the most economical routes possible to their destinations…by following the scientific evidence before them, not preconceived opinions about routes based on notions whose originators had long faded into history and beyond reproach of informed questioning. If Maury saw as far as his vision eventually led, he might even have imagined that this data could provide the foundation for scientific theories that might *predict* rather than describe, theories that further developed man's understanding of his environment. A world of possibilities lay before him for such a plan…if he could get seafarers to subscribe to it![51]

Though brilliantly simple, Maury's plan to record and disseminate vital information about weather and sea conditions that mariners could expect to encounter in their travels depended on his own ingenuity, and the brave individuality of sea captains willing to eschew tradition for science. He understood the leap of faith that he was going to ask them to make, a decision the consequences of which they would face in either smooth stretches of calm seas and favorable winds, or angry gales and crashing seas. Faith in a Higher Power was one thing for mariners; faith in a man was quite another. Maury knew the proof was in the pudding, and he set about with the same meticulous attention to detail that he had applied to his research for his paper on navigating Cape Horn. He set the midshipman he had at his command at the Depot to sorting logbooks by the geographical regions that their voyages detailed. Together they then began the laborious process of stripping information from every track recorded: winds, seas, currents, strange phenomena, precipitation, and more. Because of the number of logs that described the voyage between New York and Rio de Janeiro, he decided to concentrate his early efforts along that route. If he could convincingly demonstrate that certain conditions prevailed seasonally along that route, he might then convince some sea captains that his conclusions were feasible, or that his information should at least be put to the test.[52]

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[51] Maury, *The Physical Geography of the Sea*, v-viii.
[52] DuVal, *Matthew Fontaine Maury: Benefactor of Mankind*, 14-16; Hawthorne, *Matthew Fontaine Maury: Trail Maker of the Seas*, 82-87; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 144-157.

Maury's work with the New York to Rio logs convinced him that there were indeed patterns that emerged from the data, and he concluded that captains repeatedly had fought natural conditions rather than availing of them in their transits north and south along the East Coast of the Americas. Maury noted that by following traditional 'wisdom', captains in their voyages to Rio followed a zigzag course to avoid strong currents reputed to run near Cape St. Roque. Avoiding this area by sailing far to the east, these captains lost favorable winds and were sometimes becalmed or offset by headwinds depending on where they ended up crossing the equator. He estimated that following such a course – a practice handed down by tradition more than anything else – resulted in a track that covered a distance equivalent to three crossings of the Atlantic![53] He became so convinced that he began to lobby his Navy superiors to mandate that ships report the details he sought to further resolve the patterns emerging from the archived logs, hoping the recording and reporting of such data would become routine and not at the whim or according to the talents of the particular officer of the deck in charge of the ship's log. Late in 1842 the Bureau of Ordnance and Hydrography issued a circular directing all Navy ships to send navigational, hydrographic and meteorological information to Lieutenant Maury at the Depot of Charts and Instruments. By the time Maury accumulated enough information – *five years later* – and produced his first sailing charts in the autumn of 1847, he was so certain of his findings that an inshore route to Rio was not only possible but the best way to go, to dispel the 'bugbear' of this widely held belief that such a course was a sure recipe for disaster he named this inshore passage the "Fair Way off St. Roque" which also became known to sailors as the "Fair Way to Rio."[54]

Maury's description of his first set of *Wind and Current Charts* indicates the simplicity of his vision of a new methodology for nautical charts. In a letter to John Quincy Adams he instructed that the copy of the Gulf of Mexico chart (one of a series of eight charts of the eastern Atlantic) that he sent to the former President "exhibits the prevailing currents and winds of that region at a glance, and with a perspicuity, certainty and generalization that written accounts cannot give. Books, if I may say so, impart information through the ear – these charts through the eye, and, therefore, in a manner and form much more condensed

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[53] Maury, *The Physical Geography of the Sea*, xi.
[54] Maury, *Maury's Sailing Directions*, 143-151; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 37.

and available." He further observed that the currents in the Gulf of Mexico followed courses "as sharp in their outlines as is the Mississippi river [sic] itself." By adjusting course, vessels could turn these currents to their advantage rather than wasting time and effort stemming their flow. Maury informed the former President that another important goal of the charts was to remove "Vigias, including rocks, reefs, and shoals, which, reason of the uncertainty as to their existence and position…harass navigators, and stand in the way of commerce."[55] In his accompanying *Sailing Directions*, Maury interpreted the charts for mariners and provided his best recommendations for optimizing routes between ports based upon prevailing winds and currents, not upon tradition or superstition. His recommendation for the trip to Rio was indicative of his confidence in their work; rather than follow the easterly seaward route around Cape St. Roque, he advised mariners to, "Stand boldly on, and if need be, tack, and work by under the land."[56] Justifiably proud of the work that he and his midshipmen had accomplished, Maury had a very significant task remaining: convincing captains to use his charts!

The *Wind and Current Charts* themselves were deceptively simple.[57] Coastlines were detailed together with lines of latitude and longitude in similar fashion to the Admiralty charts that ships of the day carried. Soundings were also recorded to give the depth at various points, again something often seen on earlier charts. But from there Maury deviated, providing information where before lay blank swaths between geographic references on land and what crude bathymetry was available. First Maury plotted the tracks of the ships from whose logbooks he gleaned his information. He labeled them with the name of the ship and the year of sailing, knowing that mariners who happened to have crewed that particular vessel on that particular voyage would be able to verify the information from his own recollections of the passage.[58]

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[55] Quoted in Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 178-179.
[56] Quoted in Ibid., 179. This quote is actually a paraphrase of Maury's advice to mariners, recounted as part of a eulogy given upon his death by the President of the Virginia Military Institute, where Maury had accepted a professorship near the end of his life. Maury did in fact often advise mariners to "stand boldly on" near Cape St. Roque and to tack as needed without fearing the 'bugbear' current that was rumored to wreck ships on the lee shore. This phraseology can be found repeatedly throughout his *Sailing Directions*.
[57] The descriptions presented of *Maury's Wind & Current Charts* are taken from the charts themselves; the chart used in this instance is: Matthew Fontaine Maury, "Maury's Wind & Current Chart: No.6," in *Series A Track Charts* (Washington, D.C.: United States Hydrographic Office, 1849). Quotations not otherwise noted are from the "Notes" included on the chart – the section now more commonly called a 'legend' - so that the mariner would be able to properly interpret symbology.
[58] Maury, *The Physical Geography of the Sea*, v-vii. It must be remembered that Maury sought to convince an esoteric group of seamen about the validity of the undertaking. Sailors did not always embark in the

Vessels labeled in Roman letters indicated them as men-of-war; vessels in italics indicated that Maury was able to obtain the log of a merchant vessel to plot that particular track. He recorded the tracks in four different colors representing the season of year that the voyage took place: black for the winter months of December, January, and February; green for the spring months of March, April, and May; red for the summer months of June, July, and August; and blue for the autumn months of September, October, and November. He further refined the track by using one of three manners of line: an unbroken track represented passage in the first month each season; a broken line represented a track laid down in the second month of the season; and a dotted line indicated the voyage took place in the third month of the season for which the color of the line indicated.

The power of the *Wind and Current Charts* as a reference came in the wind data that was superimposed on these carefully reproduced record of ship tracks, and the current, temperature, and magnetic variation data recorded close by the tracks of those vessels that gathered this manner of information. Winds were denoted by brush-like symbols whose head pointed to the direction from which the winds blew, whose size indicated the relative strength of the wind, and of which the "divergence of its stiles" indicated the variation in the directions of the wind reported by the vessel at that point along its track. Brushes that were split indicated winds shifting to different quarters at different times of the reporting day. Squalls were indicated by dashes appended to the wind symbols when they occurred. Maury recorded information he obtained on ocean currents by placing arrows whose length indicated the strength of the current (also recorded in decimal notation nearby) and whose direction indicated the set of the vessel from which the current was inferred (direction of displacement). Magnetic variation of the ship's compass was inscribed in Roman numerals near the ship's track and water temperatures that were taken were recorded by numerals that were underlined. Hazards to navigation were noted including rocks and shoals with some amplifying information about the particulars of the danger. Maury's affixed his name prominently on the charts - whether as a boast or challenge it may be argued - and began a practice that persists to the present day.

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same vessels or with the same shipmates; if even one veteran of a cruise Maury annotated on his charts were present on a future voyage on a ship that carried his charts, and could verify the transcription through his own memory of the voyage, more trust might be placed that the other information was equally valid.

Navigational charts printed by the United States Government continue to bear an inscription that credits the work of Maury as the basis of the information gathered to produce each chart.[59]

The strength of Maury's charts lay in their simplicity, and as he had described to President Adams, in the ability to take in a large quantity of information at a glance. Mariners who had not traveled some particular route, or had not done so at some season of the year, could benefit from the observations of those that had traveled the routes at or near the same time of year. No guarantees existed that those particular conditions would be encountered. The prudent seaman kept an eye to the west, and paid close attention to the temperature and direction of the wind, the rise and fall of the glass (barometer), and the height and direction of ocean waves and swells to divine what weather lay in store for him. But where enough tracks were laid down for the independent mariner to conclude from his own interpretation of the data that certain conditions were likely to be encountered along his track, it allowed him to prepare himself and his ship and - if capable according to his particular situation – to alter his course to avail of conditions that might assist his travel and avoid those that might hinder his progress to his destination. With the publishing of his first series of Atlantic *Wind and Current Charts*, Maury had realized his early vision of creating commonly available information from what had been heretofore tightly guarded (or at least in the case of the Navy logs, perhaps merely overlooked or disregarded) corporate knowledge. Under wraps the possession of this information may have provided some mariners an edge, but it equally threatened to condemn them to poor choices of routes and hazardous conditions needlessly. Information freely available for public scrutiny made verification possible, and – *provided someone would use it* – would benefit all mariners in the safe and expedient passage from port to port.[60]

In early 1848, Captain Jackson of the sailing vessel *H.W.D.C. Wright* out of Baltimore took up the gauntlet. Using Maury's charts Captain Jackson sailed to Rio and back in the time that other ships often

[59] Douglas Stein, "Paths Through the Sea: Matthew Fontaine Maury and his Wind and Current Charts," *The Log of Mystic Seaport* 32, no. 3 (1980); United States Naval Oceanographic Office, *History*, July 26, 2001 (accessed May 6, 2002); available from http://www.navo.navy.mil/PAO/history.html.
[60] Maury, *The Physical Geography of the Sea*, v-xi.

took one way in the passage.[61] Sailing south, Captain Jackson made the voyage from the Virginia Capes to Rio in 38 days, 17 fewer than the 55 days the passage normally averaged. Returning north he shaved a day off that time, arriving more than a month before he was expected. News spread quickly on the waterfront. The Baltimore newspapers touted Jackson's – and Maury's – achievement. The news reached New York and Boston and other East Coast ports. Skepticism gave way to the competitive spirit of sea captains seeking any advantage they might obtain in their trade, and Maury's charts quickly developed a following. 5,000 sets of charts were distributed in short order.[62] In a stroke perhaps as brilliant as his original insights into developing the *Wind and Current Charts*, Maury devised a novel method of payment for his charts. They were free…with a condition. Together with the charts, captains received a ten-page pamphlet that Maury created so that the environmental information he needed to improve his charts might be systematically recorded by every captain that put to sea with the charts as their guide. The "Abstract Log for the use of American navigators" simply explained the *Wind and Current Charts* and included twelve blank forms on which captains were to record information at specific daily intervals during their voyage and then forward to Maury upon their return to port. With precisely the information he needed to improve upon the data he intended to provide and interpret for mariners - in *identical format* to make processing a large amount of data feasible - the *Wind and Current Charts* could be published in revised editions as Maury was able to further resolve the geophysical mysteries of the sea.[63]

Maury's Abstract Logs demanded a bit of work from the mariner in return for the knowledge imparted by the *Wind and Current Charts*. He expected slightly more from the disciplined officers of the Navy and issued them different forms from those he provided to merchant mariners. The Navy forms had 24 blocks for information that needed to be recorded for every four bells struck throughout the watch (at two hour intervals), and two special observations at 9:00 in the morning and 3:00 in the afternoon. Maury wanted naval officers to record the date, hour, latitude and longitude determined both by celestial observation and by dead reckoning (the practiced estimation by the navigator of his position based on course steered and speed recorded since the previous positional fix), magnetic variation of the compass, wind direction and

[61] Jacquelin Amber Caskie, *Life and Letters of Matthew Fontaine Maury* (Richmond: Richmond Press, Inc., 1928), 28.
[62] Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 180.
[63] Lewis, *Matthew Fontaine Maury: Pathfinder of the Seas*, 53-56.

speed, barometric pressure and temperature corrections for barometric readings, wet and dry bulb temperatures, forms and directions of clouds, proportion of clear sky, hours of (and type of) precipitation, sea state, surface water temperature, specific gravity of a seawater sample, water temperature at depth, state of the weather, and – finally – any other remarks the deck officer might have to offer including hazards to navigation sighted or other phenomena that did not fit any of the previous 23 categories (!). Merchant captains were subjected to two-thirds as many inquiries and with lesser frequency, information that conformed mostly to the type of information Maury had included in his initial *Wind and Current Charts*.[64]

Strict standards for data quality were problematic. Maury's organization at the Naval Depot for Charts and Instruments - and later when it became the Naval Observatory - was the repository for charts and navigation instruments owned and used by the U.S. Navy. Maury was therefore in a position to control and document instrument accuracy (including variation or error for specific devices) and provide for training for naval officers in taking and recording measurements. He had less obvious control over the merchants in this scheme; and given the earlier stated sentiments about the proprietary nature of seagoing knowledge, it may also be questioned as to the veracity of the data Maury received from various merchant sources (it would be of no obvious value for naval officers to misrepresent data other than to 'gundeck' observations – i.e. to provide spurious information to obscure shoddy performance). He addresses this in one instance where a captain questioned the information on his charts and in the *Sailing Directions*, "The Pilot Charts give the winds as shipmasters have reported them. Shipmasters cannot be accused by any one of conspiring to report them from the wrong points. The winds as they are entered in the logs, and reported to me, have been transferred to these charts; and Captain Windsor is too intelligent to say, that, if any one will tell him which way the winds blow in any part of the sea, it would be necessary for him to go there in order to tell what courses a ship can make good with these winds. And if he had consulted these charts, he would have perceived that the united observations of all, as therein expressed, were against the opinion of his." Maury chastised the questioning captain a bit more, "I suppose if the abstract of another vessel be produced that was making the voyage the same time as the *Rapid*, and which did take the route which Captain Windsor thinks would have put him so far ahead, that *he* will take that as decisive, in favor of the Sailing

[64] Matthew Fontaine Maury, *Maury's Sailing Directions*, Eighth ed., II vols., vol. I (Washington: William A. Harris, Printer, 1858), 339-348; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 152-153.

Directions, though he thinks so little of the united testimony which hundreds of seamen have given in, and which is embodied in the Pilot Charts."[65] By the time of Captain Windsor's remarks, made to Maury by letter sent in with his abstract log in 1856, Maury's theories held widely accepted credence, and it is perhaps from frustration that he continued to battle skeptics that his dismissive remarks appear petulant. Nevertheless it is of note that Maury considered the issue of data quality, and deliberately – if perhaps a bit unscientifically – decided to accept what mariners submitted via the abstract logs with the expectation that they were filled out in good faith for the common benefit they represented.

In the last quoted passage, Maury practiced some condemnation by faint praise before delivering his decisive refutation of Captain Windsor's temerity, but ultimately what he was addressing was really something more fundamental than the protestations of a single "doubting Thomas." What Maury asked of Captain Windsor and all others who took his charts and *Sailing Directions* to sea, was for them to put their faith – and to some not so small degree their lives and livelihood – in *science*. The data that he published in somewhat excruciatingly exhaustive detail of many individual voyages in the *Sailing Directions* was not necessary for the interpretation of his charts. It was not necessary to see the logbook data from individual cruises to heed his advice on route selection. And it was not necessary to create so voluminous a work by including the amount of detailed data that *Sailing Directions* held (the final edition had to be expanded to two volumes, two and three inches thick respectively, published in consecutive years 1858 and 1859) to make his system effective. But Maury intuited that sailors needed to see 'real' data, to recognize the routes, possibly the ships and captains that sailed them, and more than a single instance of each to convince them to give his theories some credence, enough so that they might test them out at sea.

Maury's work is also one of the earliest examples of *environmental modeling*, of using observed data to create a projection of future environmental conditions.[66] And although to the present reader this may not

[65] Maury, *Maury's Sailing Directions*, 239.
[66] This is not the case in the strictest sense of what would be interpreted as modeling, in which a variable input would produce via a model a variable output; but it is in the most basic of interpretations, which should be considered here with respect to the original application of such statistical if not truly dynamic scientific methods. By providing various 'starting points' via the examples of actual voyages, the mariner could select the closest starting conditions from the examples in front of him and project the most likely scenario of the proximate conditions along his track.

appear to be a stretch given that weather reports are essentially similar types of modeling, to this point in the 19th century the only such attempts widely available to a public audience for operational use might be those of the *Farmer's Almanack* [sic], and those were season-long forecasts not so refined by geographic position or temporality as Maury's efforts. With such an innovation and what it required of mariners, it is not surprising that his theories would take time to gain traction, and that some degree of skepticism might prevail over the validity of his data since so much depended on its reliability. Because of the ultimate success of Maury's efforts, the plaudits outshine the detractions in the historical record; history is written by the victors, and because most accounts in this present instance are available through the *Sailing Directions*, by Maury! But at the time, Maury's efforts were a work in progress, and attendant uncertainties needed to be addressed directly for his plan to succeed. Bit by bit experience would prove the ultimate arbiter, and time and trials were necessary elements.

At Sea Feb 20th 1849

> *…we are now fast approaching our destined port after a passage somewhat longer than the average, and so much more so than I anticipated, that I am afraid that we shall (with detention at Islds & Manila) not be able to save the monsoon down the China Sea. After leaving Boston we had strong southerly winds which drove us to the N & East so that we did not pass the parallel of that city until the 13th day after our departure. The NE trades were very unfriendly to us (being so far to the E I suppose) but we finally crossed the line (in 30 ½) within the average being 38 ½ days & experiencing <u>no calm</u>, so much for Maury's theory, which recommends crossing to W of 30º; had the wind permitted it was Capt E's intention to have followed the route suggested by Lieut M_ to the line; after crossing <u>northerly</u> and westerly wind carried us by St Roque without any detention, and we were then equally disappointed with the SE as we had been with the NE trades, light, variable winds from almost every point of the compass, off the La Platta we got a full share of 'Pamperas' & there had a constant succession of squalls, no one 24 hours without reefs in for 50 days, in passing the Cape we were highly favored being only twelve days from Staten land to Cape Pillar and this only, has saved our passage from the unenviable celebrity of being one of the longest. We have been fortunate in not having any severe gales, our foretopsail not having been in the whole passage, our severest weather was between 20 & 50 both sides of the Cape where we had reason to expect (from the experience of others) the finest runs, after leaving the S.E. trades to Staten land. N.W. winds prevail 9/10ths of the year; one of our passengers is on his 4th voyage round having left the same season each time & has always carried such a wind from Lat of 30º, my own experience on my 2nd voyage proves this to be the case & that of two other passengers who have previously passed this way confirm our experience whereas we had Southerly & S.W. winds mostly with northerly wind but part of two days. There is where we lost our passage as notwithstanding the light winds in the trades we made good progress through them the Leland proving herself to be quite fast going 6 or 7 knots as easily as any vessel I was ever in, 8 or 9 in a strong breeze however is the best she can do, united to her sailing qualities in light winds she is very Weatherly in heavy weather & holds on to every inch she makes tacking readily under double reefed top sails, foresail & top Main stay sail, an excellent sea boat & in fact as comfortable a ship as one would expect to go to sea in. …*[67]

[67] N. Cook, At Sea, to Capt. William Graves Jr., Newburyport, February 20, 1849, ALS, Private Collection.

It is interesting to find accounts that do *not* praise Maury's contributions to navigation, but in that this writer has obvious experience at sea and is writing to a sea captain in the port of Newburyport, Massachusetts, it would be expected that veteran mariners would be hardest on 'book' theories and provide the most critical eye to their test in practice. Nonetheless what is also interesting here is his description of the prior experience of other passengers in making the voyage around Cape Horn. It may be that Maury's theories stimulated discussion among those who went to sea in a way that otherwise might not have taken place. Also of note is his mention of the passage by Cape St. Roque, the heretofore 'bugbear' of navigational misinformation Maury worked so hard to dispel. Perhaps just this mention demonstrates the incipient confidence captains had in even defying this previous conventional wisdom due to Maury's persuasive and emphatic refutation of the hazards of navigating near this point of land. What must also be taken into account is that this letter is written only a short time after the initial issuance of the *Wind and Current Charts*, and not long after Captain Jackson's voyage publicized them to a seagoing audience. It is as well early in Maury's gathering stage when data had not resolved every season in every location with uniform statistical acceptability. Maury went with the best information he had to offer, and this only improved when mariners tested his theories and contributed to their further development through their submission of abstract logs. And it cannot be overlooked that at any given time – even in today's world with the advances that have been made in the forecast sciences – Mother Nature still has surprises that cannot be anticipated. It is only when many such accounts were considered together that Maury's charts and his *Sailing Directions* might truly be judged, and under this lens they rapidly demonstrated their worth.

Once civilian mariners supplemented the submissions made by the U.S. Navy, abstract logs poured into Maury's offices at the United States Naval Observatory, some 26 million over the course of five years.[68] Maury produced new editions of the *Wind and Current Charts* and expanded his volume of *Sailing Directions* to provide more and more interpretation of the vast quantity of data that was gathered. By 1849 Maury realized his third edition of his North Atlantic *Wind and Current Charts*, and additionally produced charts for the South Atlantic, the Indian Ocean, and finally the North Pacific and South Pacific. In addition to his Series "A" *Wind and Current Charts*, known as Track Charts because they reproduced the tracks

[68] United States Naval Oceanographic Office, *History*, (accessed).

reported from Maury's original store of logbooks and the newly received Abstract Logs from the captains who used his charts, Maury was able to produce five additional series of charts for the maritime community. His "B" Series focused on the Trade Winds of the Atlantic and the Trade and Monsoon Winds of the Pacific. The "C" series sought to handle the ever increasing volume of data and represent it in a different fashion for use by navigators and will be described in greater detail below. Series "D" were known as *Thermal Sheets* and depicted surface temperatures with a color scale, a forerunner of surface temperature charts that have become familiar in present times because of their depiction of the El Niño phenomenon in media graphics as a brilliantly colored lens of warm water in the equatorial Pacific. Series "E" provided information on rain, fogs, calms, lightning and thunder, and storms in five-degree latitude and longitude squares over the ocean, and were known as *Storm and Rain Charts*. Maury's last series of charts produced for wide consumption by mariners was his Series "F" chart, the *Whale Charts* that were used by whalers to hunt in locations where higher densities of whales had been reported in the Abstract Logs.[69]

Of particular note, Maury's Series "C" charts devised a way to view immense volumes of data in a concise, systematized fashion. This allowed Maury to include hundreds of observations in well traveled areas to provide guidance to mariners, information that would have proved worse than an eye test on a crowded chart obscured by so many intersecting tracks had they all been included on a Series "A" type chart. Known as *Pilot Charts*, these charts depicted ocean areas as a set of five-degree latitude/longitude squares. Within each square was a compass rose-like grid that radially divided the 360 degrees of the compass among 16 equal arcs (the compass rose familiar to mariners was divided into 32 points corresponding to eight major winds, eight half-winds, and sixteen quarter-winds;[70] Maury sought reporting resolution down to the level of the eight half-winds), four centered along the four cardinal points of the compass and three between each of these. Each of these wedge-shaped sectors was further divided four times by three concentric circles drawn around the center of the rose. In the middle of the diagram was a circle evenly divided into quadrants by two lines oriented north-south and east-west. Within each of the

[69] William H. Goetzmann, *New Lands, New Men: America and the Second Great Age of Discovery* (New York: Viking Penguin, Inc., 1986), 309-315; Maury, *Maury's Sailing Directions*, 281-329; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 187-188.
[70] Bill Thoen, "Origins of the Compass Rose," February, 2001 (accessed April 13, 2002); available from http://www.gisnet.com/notebook/comprose.html.

sixteen arcs were numbers that represented the number of times prevailing winds in that sector were reported. By including a tally in each of the four subdivisions of the arc, Maury was able to then separate the data seasonally for each sector. Resolving the picture down to its finest level of granularity, three numerals per subdivision further broke down the data by month. The center circle that was divided into quadrants represented calms reported in each season, three numerals per quadrant further resolving the information Maury sought to impart to a resolution of months. Though relative wind intensity was not obtained from this chart, the prevailing direction of wind – the navigator's first consideration – stood clearly out from Maury's wind rose. By consulting the Sailing direction and local Track Charts he could further estimate the strength of the blow he expected to encounter.[71]

The information on the *Pilot Chart* informed the navigator about what conditions to expect within each square of Maury's chart, a region that was generally somewhat less than 300 miles by 300 miles (depending on latitude). For voyage planning, navigators could pick their way through consecutive five-degree squares to take advantage of optimum sailing winds to reach their destinations. A powerful conclusion can be drawn from studying Maury's *Pilot Chart*. Mariners had planned their voyages in generally one of three fashions: following routes that had been passed down to them, sailing straight line courses between two points on the chart (following a rhumb line), or - as they began to understand the mechanics of Mercator projections - great circle routes that appeared on their charts to take them far out of their way but in fact were the shortest distance between two points.[72] Maury's charts changed that conventional wisdom. His early work had refuted the wisdom of blindly accepting a track of those who went first. With this series of charts, Maury demonstrated that favorable winds could be found by deviating from a rhumb line or great circle route, winds that would more than compensate for the length of the detour. He showed that in fact the 'shortest distance' – meaning the shortest time of travel – was *not a straight line*!

[71] Maury, *The Physical Geography of the Sea*, v-xii; Maury, *Maury's Sailing Directions*, 297-303. This information may also be found in the 'Note' of each of Maury's *Pilot Charts*.
[72] Bowditch, *The American Practical Navigator: 2002 Bicentennial Edition;* Weems, (accessed).

The fame of Maury's charts grew because of their use by a flamboyant segment of the maritime sailing world. In the war of 1812, the small United States Navy held its own primarily because of the speed of her small fleet in quick engagements. Veterans of the war "regarded swift ships as synonymous with life, liberty, and the pursuit of happiness."[73] Small fast merchants of the post-war years gave way by the 1830s to a new, larger and even faster breed of sailing ship. With sleek lines forward and an enlarged midsection aft of center, clipper ships were built for speed.[74] Their forte was the 15,000-mile run from New York to San Francisco, a trip that averaged 188 days. In 1852 four clipper ship captains decided to race along this route, leaving at different times, but each carrying Maury's *Wind and Current Charts* and *Sailing Directions* to guide them on their journey. *Wild Pigeon* sailed from New York in mid October; *John Gilpin* sailed two weeks later. *Flying Fish* followed *Gilpin* a few days later, and the last of the four, *Trade Wind* sailed November 14th.[75]

Although the four clipper ships left port at different times, they encountered each other on the passage because of the variable conditions each faced and speed each was able to carry along the way. Nevertheless after 15,000 miles of open sea, the race was remarkably close. *Flying Fish* made the transit in 92 days and 4 hours; *John Gilpin* followed in 93 days and 20 hours. *Wild Pigeon*, the first to sail, encountered difficulty early on and was passed by the *Fish* and the *Gilpin*, arriving in San Francisco in 118 days. The last to set sail from New York, *Trade Wind* had suffered a fire enroute that burned for eight hours, but she still arrived in port after less time at sea than *Pigeon*, taking only 102 days to make the passage.[76] Two years later, the famed clipper ship *Flying Cloud*, with Captain Perkins Creesy commanding and his wife Ellen navigating with the aid of Maury's *Sailing Directions*, set the New York to San Francisco record in 89 days and 8 hours.[77] Advantages did not only accrue to the swiftest vessels. Using Maury's *Sailing Directions*, the average time for passage from New York to San Francisco dropped from 188 days to 145.[78]

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[73] Cutler, *Greyhounds of the Sea*, 53.
[74] Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 181.
[75] Maury, *The Physical Geography of the Sea*, 269.
[76] Ibid.
[77] The Maritime Heritage Project, *Clippers*, January 12, 2002 (accessed April 12, 2002); available from http://www.maritimeheritage.org/ships/clippers.html.
[78] Williams, *Ocean Pathfinder: A Biography of Matthew Fontaine Maury*, 137.

Aside from the drama it provided during a heady time of westward expansion of the still-young United States, the four-way race and the subsequent record-setting voyage of *Flying Cloud* signified something more. Maury noted that the four ships of the 1852 race had sailed days apart over an ocean, mostly beyond the sight of land, for greater than 15,000 miles yet, "like travelers on land, bound upon the same journey, pass and repass, fall in with and recognize each other by the way." [79] He further commented upon studying their Abstract Logs that he would have made but one deviation in navigation throughout the entire length of the course from the courses chosen by the navigators of the four ships, and that for but one ship at one point along her passage. With no small amount of pride, Maury sums up his feelings for the success of his endeavor at finding the paths within a pathless sea, "Am I far wrong, therefore, when I say that the present state of our knowledge with regard to the physical geography of the sea has enabled the navigator to blaze his way among the winds and currents of the sea, and so mark his path that others, using his signs as finger-boards, may follow in the same track?"[80]

Matthew Fontaine Maury's endeavors changed the nature of ocean-going travel in the 19th century, making it faster…and safer. Although steam powered ships were operating at the time of Maury's charting efforts, a long time elapsed before they displaced sail as the primary conveyor of both passengers and cargo. Technology was applied to the construction of sailing vessels at the same time that steam power and iron hulls were making advances in the late 1800s. Copper hulled vessels under sail maintained an advantage in speed over steam-powered vessels until the 1870s, and sailing vessels dominated long-range trade. Even with the opening of the Suez Canal in 1869, and the drastic reduction in the distance that had to be traveled to reach trading centers in the East, steam did not displace sail. It was not until the 1880s that high-pressured boilers were developed that could translate to more horsepower, and steel plating construction techniques reached a level of competency such that steel vessels could withstand the pounding seas generated by the thrust of their steam powered engines. Even past this point, however, steam powered

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[79] Maury, *The Physical Geography of the Sea*, 269.
[80] Ibid., 269-270.

ships were certainly not immune to adverse sea conditions and still benefited greatly by the fruits of what grew of Maury's labors.[81]

Lieutenant Maury's plan to provide mariners with information about the sea conditions they might expect in their travels was brilliant in its simplicity, and its results proved equally spectacular. Looking at the information gathered all together – synoptically, at least for the times – Maury was able to infer the existence of ocean currents as well as persistent wind conditions (and disprove other long-held beliefs) that could be used to the mariner's advantage. Convincing a few daring captains to utilize his charts to plan their voyages instead of relying on the time-trusted routes passed to them in their days of apprenticeship, Maury was able to win the trust of a broader community of seafarers after these captains met with spectacular success. From that point forward Maury's charts grew upon the success of earlier editions with a steady flow of information to revise and improve them. Records fell as sea captains strove to out-do each other applying Maury's charts and theories to their voyages. The popularity of the *Wind and Current Charts* was aided by the contemporary discovery of gold in California that created enormous demand for passage from the East Coast of the United States around Cape Horn to San Francisco, a passage the *Charts* drastically shortened. Upon reflection, it is difficult to say whether Maury's career would have led him to the Depot of Charts and Instruments and the store of logbooks that stoked his imagination, and that led eventually to the development and great success of his *Wind and Current Charts*, had he not been lamed in the stagecoach accident in 1839. But it seems unlikely. Though he cursed it at the time for derailing his naval career, his accident proved his greatest boon, one that perhaps would never have been realized had his seagoing career followed a different track.

Pandora's Sea Chest

Matthew Fontaine Maury's researches into the mysteries of the oceans began for a very simple reason: Maury wanted to perform to the best of his ability in his assignment as sailing master of *USS Falmouth*. During his time as a midshipman he had clearly recognized the need for a better way to instruct junior

[81] Gerald S. Graham, "The Ascendancy of the Sailing Ship 1850-85," *The Economic History Review* 9, no. 1 (1956): 74-78.

naval officers in general, and this eventually led to his first major publication on the essential science of navigation, an accomplishment that did much to make Maury's name known within his service. But it was effort at scientifically describing the environmental conditions that faced mariners on the voyage around Cape Horn that started him on the path that would lead to the groundbreaking (sea – parting?) work he did in oceanography. And this began of his frustration at (not) finding information that might assist him in planning for his first voyage as the navigator of a U.S. Navy warship. Nudged by fate and fortune in this direction, Maury leveraged the interest of the United States Navy (and his professional reputation garnered with the laurels of his text on navigation) and the United States Government in making the necessary investments in his researches and the various schemes he endorsed to obtain data to improve his charts and publications. Somewhere along the way these efforts bore fruit that even Maury might not have anticipated, and the ramifications reverberate to the current day. Ripples on the water provide surface traction to winds that enable something large to grow from something small – many of the powerful waves and currents of the sea result from the cumulative effect of many small transfers of energy at the ocean-atmosphere interface. And in this sense the ripples Matthew Maury made in the field of oceanography – as they reached into other areas where the ocean environment intersects with security bringing together forces theretofore not engaged – grew to become more like powerful riptides.

As an American naval officer, it would not have been surprising had Maury advocated that the use of his charts be restricted to United States naval and merchant vessels as a matter of the interconnected economic and national security concerns of the fledgling nation. But Maury's vision was broader. Perhaps his perspective was untainted by centuries of continental warfare, and bolstered by an insular sense of security that two vast oceans provided his homeland. Maury was certainly an active proponent of American expansion and the extension of her commercial interests. He almost single-handedly crafted an expedition to explore the Amazon (that was conducted by his brother-in-law) to scope prospects for commercial exploitation of the region. He had come to view the Amazon basin (through study of his geophysical data) as a natural extension of American territory and influence that fit well within the American foreign policy of hemispheric involvement known as the Monroe Doctrine. A native Virginian, he also saw this region as a 'safety valve' for the growing Negro slave population of the American South,

an area where slavery remained legal and to which excess slaves could be sent.[82] Though he himself opposed the practice of slavery, he saw little hope for the South to give it up, especially out of spite for Northern sentiments to such effect; throughout the period of the 1840s and 1850s – the apogee of Maury's success with the *Wind and Current Charts* – the hostility and resentment that developed between Northern and Southern states festered openly.[83] Maury could have kept his discoveries close to his breast, either for the benefit of the United States, or perhaps even – given Maury's open support of southern states rights – for the benefit of mariners of his home region if any way existed to sequester information for the exclusive use of those he released it to. He did not.

Maury's interest in the marine environment was extensive, and to his credit – even though he was not by education or training a *scientist* – he recognized that there were no artificial boundaries that enclosed this environment from the forces that shaped the physical environment ashore and *vice versa*. He recognized the moderating influence of the marine environment on continental climate, taking particular note of the manner in which the Gulf Stream warmed northern Europe.[84] He also recognized that conditions over the continents would eventually impact the seas; a chapter of *The Physical Geography of the Sea* is dedicated to the study of "Red Fogs and Sea Dust" – the precipitation of particulate matter picked up over land and deposited over the surface of the ocean. Maury focused on the air-sea interaction so essential to both the circulation of the oceans and of the 'ocean' of air above. His recognition of this essential coupling of the fluid media of air and water led to later editions of his signature work bearing the title: *The Physical Geography of the Sea and Its Meteorology*. Maury's interest in the patterns of the air over continental regions was not uniquely due to his interest in their effect on the oceans. Born to a farming family, he believed that better resolution of atmospheric circulation held great benefit to agriculture as well. When the new medium of telegraphy made its appearance in the 1840s, Maury was an early proponent of its use to transmit weather data so that it might be synoptically assembled (near–real-

[82] Donald Marquand Dozer, "Matthew Fontaine Maury's Letter of Instruction to William Lewis Herndon," *Hispanic American Historical Review* 28, no. 2 (1948).
[83] Caskie, *Life and Letters of Matthew Fontaine Maury*, 119-120; Hinton Rowan Helper, *The Impending Crisis of the South: How to Meet It* (New York: A. B. Burdick, 1860); "Maury's Efforts to Avert War," *Confederate Veteran*, February 1924, 48-49.
[84] Matthew Fontaine Maury, *The Physical Geography of the Sea and Its Meteorology*, Eighth ed. (London: Sampson Low, Marston & Company, 1860), 51-75.

time study, or post analysis of data taken at the same time, over a broad area) for analysis and prediction to aid farmers - a plan that was years later adopted by the U.S. Weather Bureau. This interest in meteorology in general would lead to one of Maury's most lasting contributions to science and to mankind.[85]

In 1851 the United States Government received a proposal from Great Britain suggested by the Royal Engineers to engage in a joint system of land meteorological investigations. This was sent to the Army, but also to the Navy where it made its way to Maury's desk at the Naval Observatory. Taking the synoptic view, Maury suggested that perhaps this effort should not be confined to land observations, and perhaps it should not only be confined to the efforts of these two nations, "…no general system of meteorological observations can be considered complete unless it embrace the sea as well as the land. The value of researches conducted at this office with regard to the meteorology of the sea would be greatly enhanced by co-operation from the observatories on the land…"[86] Maury then went on to make a critical suggestion to the scheme, "I respectfully request that as an amendment to the British proposition, a more general system be proposed: that England, France, Russia and other nations be invited to cooperate with their ships by causing them to keep an abstract log according to a form to be agreed upon and…devising, adopting and establishing a universal system of meteorological observations for the sea as well as for the land."[87] When the Royal Society indicated its disinclination to support an expansion of a combined system of land observations to a larger number of nations, but upon review of Lieutenant Maury's proposal endorsed such a suggestion for the collection of marine data, Maury recommended to the United States government that the land portion be dropped from the plan. The United States Government thereafter "proposed a uniform system of observations at sea, and invited all the maritime states of Christendom to a conference upon the subject."[88]

[85] Maury, *Maury's Sailing Directions*, iii-ix. In the "Introduction," Maury expounds upon the usefulness of his researches to farmers and others more interested in terrestrial rather than marine interests. His coupling of the ocean and atmosphere with regards to patterns of weather were far before his time and even now the two fluids were only recently integrated in the last decade of environmental models; in part this is due to computational limitations, but it is also a matter of more comprehensive acceptance of the marine influence over land.
[86] Quoted in Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 206.
[87] Quoted in Ibid., 207.
[88] Maury, *The Physical Geography of the Sea*, xii.

In his introduction to *The Physical Geography of the Sea*, Maury enthusiastically described the results of the conference, held in Brussels in August, 1853. Representatives from France, England, Russia, Sweden and Norway, Holland, Denmark, Belgium, Portugal, and the United States agreed to a plan of observations that would be followed by vessels of their nations. Prussia, Spain, the free city of Hamburg, the Republics of Bremen and Chili, as well as the Austrian and Brazilian empires subsequently signed on to the plan. The agreement reached by these parties was nothing short of revolutionary: "In peace and war these observations are to be carried on; and, in case any of the vessels on board of which they are conducted may be captured, the abstract log – as the journal which contains these observations is called – is to be held sacred."[89] Maury rhapsodized on, "Rarely before has there been such a sublime spectacle presented to the scientific world: all nations agreeing to unite and co-operate in carrying out one system of philosophical research with regard to the sea. Though they may be enemies in all else, here they are to be friends. Every ship that navigates the high seas with these charts and blank abstract logs on board may henceforth be regarded as a floating observatory, a temple of science."[90] The same charts-for-abstract logs scheme that Maury so successfully put in place in the United States was made the centerpiece of the agreement. Maury lamented the fact that this system of observations extended only to the seas, but reported that steps were under way to make this a more general meteorological cooperation; and indeed today, the World Meteorological Organization considers the 1853 Brussels Conference its founding event.[91]

The Brussels agreement might have proved only to be 'lip service' by the governments that signed on, but this form of political gamesmanship that today seems to shadow some international pacts did not appear to be in effect. In the last edition of *Maury's Sailing Directions*, published in 1858, it is reported that "the most experienced seamen, the ablest navigators, the wisest philosophers, the greatest statesmen, and the most powerful nations, have given it not only their approval, but their encouragement; they have lent it their aid also."[92] The Holy See had even established a decoration awarded by the Papal States to those of

[89] Ibid., xiii. No references were found in the course of this current research to indicate that this provision was in fact observed by belligerents in some future conflict after this agreement was made.
[90] Ibid.
[91] Ibid; Richard A. Shafter, "What's in a Name: The *USS Maury*," *Our Navy*, January 1943; "The WMO Voluntary Observing Ships (VOS) Scheme," 2002 (accessed April 1, 2002); available from www.vos.noaa.gov/wmo.html.
[92] Maury, *Maury's Sailing Directions*, iv.

its subjects that maintained the abstract log established by the Brussels Conference.[93] Maury reported to that point in time having issued more than 210,000 sheets of the *Wind and Current Charts*, and published more than 20,000 copies of *Sailing Directions*. Of the estimated 137, 450 "coasters, fishing-smacks, river craft, and vessels of all sorts" estimated in the 'various States of Christendom' in the year 1858, Maury claimed that 124, 150 – the vessels of England, the United States, France, Russia, Sweden and Norway, Denmark, Holland, Belgium, Prussia, Hamburg, Bremen, Portugal, Spain, Sardinia, the Papal States, Austria, Brazil, Chili, and Peru – were cooperating in the plan. Only those 'Christian' states of Tuscany and Naples, Greece, the German Principalities, and the Sandwich Islands did not to that time participate. Of these numbers it is sure that not all vessels in fact maintained the abstract logs; Maury estimated that perhaps only one-tenth that number were engaged in foreign trade, and then only one-half that number were capable of contributing.[94] Nevertheless, of the nations then dominating international commerce it was clear that Maury had assembled an unprecedented level of cooperation. Subsequent to the Brussels Conference well over twenty five million Abstract Logs were submitted; of these only five and a half million came from American vessels.[95]

On Christmas Eve 1853, the steamer *USS San Francisco* put to sea from New York on a voyage to the West Coast of the United States. Some 300 miles from departure she encountered hurricane-force winds and her decks were swept clean by broaching seas, taking 179 souls to their deaths.[96] "A widespread anxiety prevailed in our whole country, for upon her was a whole regiment of United States artillery, *en route* to California round the Horn. By the breaking off of the upper deck, Colonel Washington, Captain Taylor, and several hundred officers and men were swept away. The hull was left drifting, with hundreds of men, women, and children of the regiment, - where, no man could say."[97] She was apparently a victim of what later became known as the 'North Wall Effect', a phenomenon of high winds and seas that can

[93] Ibid.
[94] Ibid., vii.
[95] James R. Werth, "Maury - First American International Leader," *The Southern Literary Messenger* III, no. 10 (1941): 475; A.B.C. Whipple, "The Ordeal and Triumph of Lieutenant Maury," *Smithsonian*, March 1984, 180.
[96] Maury, *The Physical Geography of the Sea*, 57.
[97] Dabney Herndon Maury, *Recollections of a Virginian in the Mexican, Indian, and Civil Wars*, Second ed. (New York: Charles Scribner's Sons, 1894), 84.

arise suddenly at the northern edge of the Gulf Stream when cold winds from across the continent pass over the warm interface of the current.[98]

San Francisco was left helpless along the edge of the Gulf Stream and although she was sighted each of the following two days by vessels bound for New York, they were unable to render assistance. When these vessels reached port and the news was sent on to Washington, the Secretary of the Navy ordered two revenue cutters to her aid. But first word was sent to Maury at the Naval Observatory to see if his research might assist in directing the rescue vessels. Maury prepared a chart of the Gulf Stream for the winter season based upon his latest intelligence (the boundaries of the Gulf Stream shifts continually, but with some seasonal regularity). From the last known position of *San Francisco*, Maury plotted drift limits within which he felt she would be found based upon the time it took for the rescue vessels to reach the vicinity, and then prescribed a course that would most likely intercept the drifting *San Francisco* or speak vessels bound for port that might have seen her. In the intervening days, the Scottish vessel *Three Bells* happened upon the derelict and stayed to windward until the violent conditions abated, after which she and two other vessels that arrived on the scene, the *Kilby* and the *Antarctic*, removed five hundred survivors from the *San Francisco*. Although the cutters sent from port to *San Francisco*'s aid arrived on the scene after the rescue had been completed, the hulk was found almost precisely where Maury had predicted they would intercept its drift. Maury noted with interest that the rescue vessels sent from port were able – with only the information available at the observatory and Maury's "system of philosophical deduction"- to find the hulk after venturing over three hundred miles, while one of the vessels that had assisted in rendering *San Francisco* aid lost sight of her overnight and subsequently had no idea where to look for it.[99]

Search and Rescue was in its infancy at the time *San Francisco* was rendered helpless in 1853. Serendipity was the only chance vessels that foundered on the high seas could hope for – the possibility that a passing ship might be near enough to witness their distress and render aid. The U.S. Revenue Cutter Service sailed nearshore waters as early as 1831 in high traffic areas where there was a higher probability

[98] A good discussion about the origins and severity of the North Wall effect may found online: Naval Atlantic Meteorology and Oceanography Command, *The North Wall...* 2001 (accessed January 18, 2005); available from https://weather.navy.mil/nwall2001.ppt.
[99] Maury, *The Physical Geography of the Sea*, 57-58.

of encountering vessels in need of assistance. Volunteer shore based services were in existence even earlier, and became part of the government's responsibility in 1848.[100] But there was little expectation that rescue might be possible on the wide expanse of the open ocean, even if word reached port that a vessel was in need of assistance. Maury's feat had demonstrated that even a slim chance was a solid chance if it were more than a random search, and would lead to an important and valuable service of military oceanography.

A small article in the newsletter of one of the United States Navy's warships in World War II, the battleship *USS Washington BB-56*, trumpets this fact in late 1941. No doubt is left about the origin of the information in question, "Many seamen whose vessels have gone down during the present war owe their lives to the information collected by Lieutenant Matthew Fontaine Maury from the logs of men-of-war and merchantmen between 1848 and 1861 when he headed what is now known as the U.S. Navy Hydrographic Office." The article quotes a Dutch captain who braved the German submarine blockade of England when he described the utility of charts that annotated prevailing winds and currents for crews set adrift in lifeboats after being torpedoed near Freetown, Sierra Leone, "…one has to steer North of N.N.E. to reach the shore of Freetown. A boat steering true East (the shortest distance as the crow flies) will never get to the shore but driven along the coast into the open by the strong Equatorial Current settling along the coast."[101] When the United States entered World War II, survival charts providing just this type of wind and current information were printed on silk and issued to aviators who faced the possibility of being shot down over Pacific waters and set adrift in life rafts.

Another famous incident of the 1850s involving the U.S. mail steamer *Arctic* demonstrated Maury's central involvement and growing influence with respect to the safe navigation of the oceans. *Arctic* collided with the French steamer *Vesta* near Cape Race, Newfoundland and between the passengers and crews of both vessels more than three hundred lives were lost. This enormous tragedy spurred discussion about how to mitigate the loss associated with such events; improved life preservers and lifeboats were

[100] Dennis L. Noble, *A Legacy: The United States Life-Saving Service*, 2001 (accessed January 18, 2005); available from http://www.uscg.mil/hq/g-cp/history/h_USLSS.html.
[101] "Century-Old Research Aids Survivors of Ship Sinkings in Current War," *Cougar Scream* 1, no. XXIV (1941).

discussed along with water-tight compartments for ships, as well as stationing bills to facilitate the chaotic process of abandoning ship.[102] But others put their efforts into preventing such tragedies altogether and Maury fell into this camp. After the *Arctic* disaster he proposed, and proceeded to mark on his *Wind and Current Charts*, Steam Lanes between America and Europe. Maury felt that "by establishing a lane or strip of ocean for the steamers to go in, and another for them to come in, the liability to danger from collision between steamer and steamer, as well as between steamers and sailing vessels, will not only be lessened, but a new resource upon the high seas will, in many cases of wreck and disaster, be afforded to those in distress."[103]

By virtue of the data he collected via the Abstract Logs, Maury was able to show that in the middle of the busy North Atlantic sea lanes near Newfoundland and Nova Scotia, calms and fogs were predominantly coincident events. With no wind, there was little danger of collisions between *sailing* vessels; but with no corresponding ability to maneuver, sailing vessels were also vulnerable to being run down by steamers in these situations of low visibility. Maury went on to design the Steam Lanes with attention to the geophysical parameters that distinguished his other aids to mariners. He suggested the route to Europe follow a southern track to avail of the following current of the Gulf Stream, and he took pains to design the northern route without placing it in too great a danger of icebergs. In his *Sailing Directions* he advocated their use and sought the agreement of sailing captains to avoid the lanes and to pass through them quickly if they had to do so.[104] Maury also received the endorsement of shippers and insurers who were already enamored of the savings he had demonstrated to their industries from his earlier work.[105] Others may have proposed such a scheme for ocean going steam travel, but Maury was eminently qualified to bring it to serious international attention. His advocacy for these lanes was interrupted by the Civil War in the United States and subsequent fall from grace as a result of his decision to fight for his native Virginia. With the enormity of the Civil War and the loss of Maury's voice on the subject, the proposal languished. But the safety the Steam Lanes represented was not of passing occurrence, and they were eventually agreed to by

[102] Maury, *Maury's Sailing Directions*, 71.
[103] Ibid., 71-72.
[104] Ibid., 72.
[105] Ibid., 73.

the major transatlantic steamship lines just before the turn of the century with only minor alterations to Maury's original scheme.[106]

Maury's interest with designing the Steam Lanes as a matter of maritime safety, together with the particulars of the S*an Francisco* affair demonstrated another element that was new to the maritime community but represented a great danger to all ships at sea. Maury pointed out that in times of reduced visibility – at night or in times of rain or fog – the danger of running into a stationary vessel was elevated. This was always the case for steamers with independent propulsion, but it also held for sailing vessels in conditions of reduced visibility when they still had winds and remained under sail. Once vessels such as *San Francisco* were incapacitated, they became hazards to navigation – derelicts that inhabited the sea ways, and constant dangers for collisions. They were not unrecognized dangers: "Of all the features of the ocean, none appeals so strongly to the fancy and none offers greater and more secret danger to the navigator than derelicts. Under no human guidance, at the mercy of winds which often drive them with great speed, and drifting oftenest in those very currents that form the most frequented ocean highways, these abandoned vessels offer a menace…"[107]

Near the end of the century, governments authorized naval vessels to torpedo those they encountered, but most were left to sink naturally. The United States Hydrographic Office estimated that 1,628 derelicts were sighted on the North Atlantic over a seven year period of the 1890s. An average year saw 232, but in 1893 some 418 such vessels were sighted. It was estimated that the average survival time of a wreck was one month, leaving some 19 afloat at any given time in the North Atlantic. Some fifty ocean going vessels were known to have collided with derelicts over the same seven year period of the 1890s, but in addition some unexplained losses were attributed most likely to this cause.[108] This particular hazard does not seem to have firmly grabbed Maury's attention, but steam travel was still in its early stages while he conducted his researches; had he remained in his office without interruption through the 1860s it most likely would

[106] David L. Cohn, "Pathfinder of the Seas," *Reader's Digest*, July 1940; *The Titanic Disaster, Steamship Lanes, and the Establishment of the Ice Patrol: The 1912 Report of the Hydrographer, U.S. Navy* (Washington: Hydrographic Office, 1913).
[107] Theodore Waters, "Guarding the Highways of the Sea," *McClure's Magazine*, September 1899, 412.
[108] Ibid., 412-413.

have, as he clearly saw the danger of vessels that were becalmed in the path of others at times of reduced visibility. Either way, by the end of the 19th century the Hydrographic Office - Maury's old command - was responsible for annotating these floating wrecks as they were reported on the charts that they issued, and Maury's researches provided the basics for attempts to model their behavior in order to avoid these hazards at sea.

Matthew Fontaine Maury's charts were most evidently useful for sailing vessels, ships that depended on the very forces the charts illustrated for their propulsion. It is of some irony then that such a fundamental shift in the views of the oceans which mariners had sailed for hundreds of years occurred at a time when sail was steadily but surely giving way to the steam boilers, wheels, and screws of the Industrial Revolution. It is possible however, that Maury's charts actually made this transition a more successful one. It is evident that Maury made the navigation of sailing vessels more safe and efficient by ensuring a greater regularity of their passages between ports, and through winning the confidence of captains such that his recommendations of safer and more efficient routes would be heeded. By saving the carrying trade millions of dollars through reducing the number of days at sea on any given passage and concomitantly reducing the probability of damage or loss to ocean storms, it is possible that sail remained an efficient competitor to steam for longer than it otherwise might have proved. It is logical then that the safety and efficiency of steam vessels had to reach a higher standard before reaching the level of profitability that eventually eclipsed sail.

If these market forces were at play, then in an indirect way, Maury's *Wind and Current Charts* also made *steam travel* more safe and efficient. Irrespective of this possibility, it must be remembered that steam vessels also contend with winds and seas that could assist or retard their progress, and to this day account must be paid to high winds and seas capable of sinking or damaging even the largest vessels that travel the world oceans. Optimum Track Ship Routing, a service by which routes of ocean passage are recommended with regards to weather and sea conditions versus length of track and fuel economy, is a

routine element of voyage planning.[109] Maury's researches and many of his findings have never lost their relevance.

Ex Scientia Tridens

Matthew Fontaine Maury was instrumental in the establishment of a shore-based school for naval officers at Annapolis, Maryland: the United States Naval Academy. In 'anonymous' letters to the *Southern Literary Messenger*, he had advocated for many different naval reforms, among them a school where formal courses of instruction might complement the seagoing training of junior officers.[110] The motto chosen for that school, the one that adorns the Class Rings of its graduates, is *Ex Scientia Tridens*: *From Knowledge, Sea Power*. It is a fitting motto for a school so akin to Maury's philosophies. But if knowledge is power, then that power is wielded by those that possess it both for good and for ill. Although Maury clearly saw the approach of the confrontation between the states of the North and South in what would ultimately become the United States Civil War, he most likely did not see the turn of events that would see his researches wielded to achieve sea power – against the very government that sponsored it. There is no evidence that Maury did anything but work diligently in the interests of the federal service up to the close of business hours on the day he submitted his resignation, having turned in for publication only two days earlier a work he considered one of his greatest contributions to navigation, *The Southeast Trade Winds of the Atlantic*.[111]

But one of the United States' most famous naval officers had 'gone South' and he was not to be forgiven this slight. When the Boston papers advertised a $5,000 reward for the head of Jefferson Davis, the former Secretary of War and recently appointed President of the Confederacy, two other rewards offered $3,000 for an army general and for "the Head of the Traitor, Lieut. Maury."[112] Maury was accused

[109] Bowditch, *The American Practical Navigator: 2002 Bicentennial Edition*, 545-556.
[110] Lewis, *Matthew Fontaine Maury: Pathfinder of the Seas*, 26-43.
[111] Hearn, *Tracks in the Sea: Matthew Fontaine Maury and the Mapping of the Oceans*, 222; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 363-364.
[112] Quoted in Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 370. In the first copy of *The Physical Geography of the Sea* obtained by the author for research into the military applications of oceanography, Maury's name had been circled in pencil on the title page; next to this graffiti was inscribed

of various acts of treason – treason because his resignation was not accepted by President Lincoln – including the removal of lights from lighthouses on Virginia Rivers, navigational buoys, and having removed maps from the observatory of southern states, charges he flatly denied.[113] His successor at the Naval Observatory, Commander James Gilliss, promptly discontinued publication of Maury's charts and the program of observations that was designed to improve upon them.[114]

Matthew Fontaine Maury's service to the South in the Civil War was not of the same nature as the duties he performed in the federal service. Maury was commissioned a Commander in the Confederate States Navy and was appointed chief of the Naval Bureau of Coast, Harbor, and River Defense. He literally worked out the principles for the first successful electrically controlled submarine mine in the bathtub of his wartime residence in Richmond, a device later said to be responsible for the loss of more federal vessels than all other causes combined.[115] Maury twice turned down enticing offers, from Archduke Constantine, the Grand Admiral of Russia, and from Napoleon III of France to quit the Confederacy and work under their patronage in Russia or France, choosing instead to cast his lot with his native state and brethren.[116] To avail of Maury's international acclaim – and because political and professional jealousies were rampant in the newly formed Confederate government and military forces – he was dispatched to England on a clandestine mission to obtain vessels for the South's nearly non-existent Navy and the more openly avowed aim of raising the stock of the Confederacy among the governments of Europe.[117]

Maury achieved limited success in the more discrete of his aims, and only debatable success in the latter; although Maury and other Confederate envoys were well received by the courts of England and

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one word: traitor. That anonymous sentiment served in no small part to animate the author's interest in Maury's work and its impact upon world events.

[113] Ibid., 371.

[114] Hearn, *Tracks in the Sea: Matthew Fontaine Maury and the Mapping of the Oceans*, 246.

[115] Kara Kaufman, "Matthew Fontaine Maury: Unrecognized Confederate Hero," *Civil War*, July - August 1993, 32-33; E.B. Potter, *Sea Power: A Naval History* (Annapolis: Naval Institute Press, 1981), 129; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 390-394.

[116] Philip Van Doren Stern, *The Confederate Navy: A Pictorial History* (New York: Doubleday & Company, Inc., 1962), 120; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 384-385, 390.

[117] Kaufman, "Matthew Fontaine Maury: Unrecognized Confederate Hero," 33; Shafter, "What's in a Name: The *USS Maury*," 45; Stern, *The Confederate Navy: A Pictorial History*, 121.

France, neither these or any other European nations were ever convinced to overtly support the Southern cause. Maury was able to obtain a vessel that was commissioned as *CSS Georgia* that went on to a successful career as a raider of Northern commerce, capturing nine Union vessels and burning five of them. The only other vessel he procured, *CSS Rappahannock*, never made it see as a raider. It was effectively bottled up in the French port of Cherbourg by the Union Navy, nevertheless contributing to the effort by forcing the Union Navy to maintain 'blockaders' throughout the war.[118] With no real designs at challenging the Union Navy other than on the rivers of the Confederacy, the South had committed to a *guerre de course*, a naval strategy of commerce raiding. And although the two vessels Maury personally procured for the Confederacy met with only moderate success, other raiders were to make a decidedly larger impact - in some measure thanks to the works Maury had contributed to the maritime world before the war even began.

Perhaps the greatest issue of contention between the United States and Great Britain immediately after the U.S. Civil War was the tacit assistance that country had provided the Confederacy through its lax enforcement of its own declarations of neutrality by allowing the ships that became Confederate raiders to be built in British ports, crewed largely by British sailors, and armed with British munitions even if this last factor of armament was accomplished under dubiously legal conditions outside of British territorial waters.[119] The American press was incensed with the British demonstration of 'neutrality' and was convinced that England sought to regain the carrying trade that had largely shifted to American bottoms over the preceding decades before the war. More than 110,000 tons of Union shipping was sunk, and some 800,000 tons was sold to foreign owners to protect them from the predation of the Southern assault.[120] American dominance did not in fact recover after the Civil War, though not solely because of the actions of the Confederate raiders. The matter of British complicity was not resolved for seven years, but under the terms of the *Alabama Claims* arbitration, Great Britain paid the United States over fifteen million dollars to account for the damages inflicted by these British-built commerce raiders during the war. Even this large

[118] Chester G. Hearn, *Gray Raiders of the Sea: How Eight Confederate Warships Destroyed the Union's High Seas Commerce* (Camden: International Marine Publishing, 1992), 237-245; Stern, *The Confederate Navy: A Pictorial History*, 186-187.
[119] Stern, *The Confederate Navy: A Pictorial History*, 32-38, 166-167.
[120] Hearn, *Gray Raiders of the Sea: How Eight Confederate Warships Destroyed the Union's High Seas Commerce*, xiii-xv.

sum does not give the accurate scope of the success of the Confederate *guerre de course*, for in the final decision the court of arbitration limited the claims tendered by the United States to only the depredations of three raiders (of eight) and of their four auxiliary tenders.[121] These three however - *CSS Alabama*, *CSS Florida*, and *CSS Shenandoah* -were the scourge of Union shipping, and in these vessels the power of the knowledge Matthew Fontaine Maury had provided the maritime world was put to effective – if deadly – purpose.

Captain Raphael Semmes was the only confederate officer of the Civil War to achieve flag rank in both the Confederate States Navy and the Confederate States Army, but his lasting fame was a legacy of his days of lesser rank as the commander of the 'rebel raider' *CSS Alabama*. From September 1862 until June 1864 when she was hulled by cannon fire from *USS Kearsarge* and sent to the bottom off Cherbourg, Semmes' command roamed the world's oceans to international renown.[122] The 220 foot, 1,040 ton cruiser chased down under steam and sail some 66 prizes that she sank, burned, bonded or sold, individually accounting for almost half the damages awarded under the *Alabama Claims* arbitration. But one of these vessels was a warship, *USS Hatteras*, and she was more a victim of her own vigilance having attempted to chase down *Alabama* as she approached a Union blockade early in her career as a raider. Semmes did not intend to risk his vessel in battle with Union warships, but sought instead vessels that carried Union commerce to demonstrate to the world audience that the Confederate States possessed naval power that could inflict palpable harm to the Union. With a good enough showing perhaps some of those nations might be persuaded into more open support for the South.[123]

As the builder, equipper, and to some degree personnel pool for Southern raiders – not to mention the beneficiary of a depleted American carrying trade - Great Britain was far from a passive observer and the South's most desired partner to counter the strength of the Union Navy that was choking Southern ports

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[121] James Tertius deKay, *The Rebel Raiders: The Astonishing History of the Confederacy's Secret Navy* (New Yorrk: Ballantine Books, 2002), 213-245.
[122] In 1996, while this author was stationed aboard the third U.S. Navy vessel to bear the name *Kearsarge*, a group of midshipmen from the Naval Academy visited for an underway exercise. One midshipman bore an intriguing nametag: SEMMES. To the question, "Are you?" the answer was, "Direct, Sir."
[123] Hearn, *Gray Raiders of the Sea: How Eight Confederate Warships Destroyed the Union's High Seas Commerce*, xiii-xv; Raphael Semmes, *Memoirs of Service Afloat During the War Between the States* (Baltimore: Kelly, Piet & Company, 1868), 92-93.

with an ever-tightening blockade. A contemporary political cartoon in *Harper's Weekly* lampooning Britain's neutrality clearly identified this conflict of interest, describing the policy as a "distinction with a difference." The British caricature of a top-hat wearing John Bull has a £ symbol in its 'blind' eye to Captain Semmes' predations while exhorting, "All right Semmes! Fire away!" In the direction of a Union gunboat, the bull's other eye is wide open and its fist raised with a less supportive gesture, "Be off there you D----d Yankee!" Its caption is crystal clear: "A few more Pirates afloat, and I'll *get all the carrying trade back into my hands*."[124] Union response to the South's choice of *guerre de course* was limited in its options. The asymmetry of the South's naval assets with respect to the Union Navy was mirrored in the commercial trade; the South largely lacked a merchant fleet, so it could not suffer similar losses if the North attempted to utilize this tactic in turn.[125] The Union was forced to chase the *Alabama* the world over with little apparent appreciation for the nature of the tactics it employed, although the key was most likely within reach of the chart table. While Union warships followed rumors and ghosts, Semmes followed the *guerre de course* strategy with a vengeance; and by applying to his tactics the researches and recommendations of Matthew Fontaine Maury, became perhaps the first naval commander to deliberately utilize geophysical data for military advantage.

Captain Semmes first flew the Confederate flag from a converted steamer christened *CSS Sumter* after the initial Confederate victory in forcing that fort in Charleston Harbor into submission in the opening days of the Civil War. In this vessel he demonstrated his intent to follow a *guerre de course* strategy, immediately voyaging to the sea lanes near Cape St. Roque, Brazil. He figured to surprise Yankee merchants who had little likelihood of even knowing that war was afoot - and even those that did would not expect a Confederate warship so soon in their midst – in order "…to do the enemy's commerce the greatest injury, in the shortest time."[126] Some fifteen years after Maury's charts and *Sailing Directions* demystified the 'bugbear' of Cape St. Roque, merchant traffic flowed north and south along the east coast of South American and Semmes determined to venture in and out of these lanes taking a toll of Union shipping, a

[124] "John Bull's Neutrality - A Distinction With a Difference," *Harper's Weekly*, November 1, 1862, 704.
[125] Charles M. III Robinson, *Shark of the Confederacy: The Story of the CSS Alabama* (Annapolis: Naval Institute Press, 1995), 7-8.
[126] Semmes, *Memoirs of Service Afloat During the War Between the States*, 105.

strategy he followed to great effect.[127] *Sumter* took seventeen ships and became the object of an intense patrol by no less than five Union warships, an action that took them from the blockade of Southern ports at a time when ships were still scarce and the blockade a rather porous one.[128] This in itself is significant, as under international law a blockade must be effective if it was to be respected by neutrals; it could not be a blockade in name only. *Sumter* was eventually pursued to Gibraltar, where Captain Semmes was forced to decommission her when three Union warships prevented her from coaling and escaping to sea. The little converted steamer had accomplished an important mission, however, and her captain and experienced officers would return to sea in confederate raiders with even greater effect.

Maury's *Wind and Current Charts* and *Sailing Directions* had led to such savings in time at sea that they became part of the same rigid tradition of the sea as the earlier paths sailors had sailed based upon the passdown of their forebears, even though Maury did not advocate such blind faith.[129] And this regularity of route made the commerce of the Union merchant fleet relatively easy pickings, especially at a time when it took months for word to be passed that a wolf was among the sheep of the open ocean. Captain Semmes took notice, "And when we reach the equator, there is another crossing recommended to the mariner, as being most appropriate to his purpose. Thus it is, that the roads upon the sea have been blazed out, as it were – the blazes not being exactly cut upon the forest-trees, but upon the parallels and meridians. The chief blazer of these roads, is an American, of whom all Americans should be proud – Captain Maury…has so effectually performed his task, in his "Wind and Current Charts," that there is little left to be desired. The most unscientific and practical navigator, may, by the aid of these charts, find the road he is in quest of."[130] Maury's charts effectively laid out Semmes' hunting grounds, and his subsequent command, *CSS Alabama*, was locked and loaded. He first hunted in the whaling grounds near the Azores where Maury's charts indicated there were whales at that time of year that whalers returning to New England might pursue to 'top off' their remaining barrels.[131] He then moved north into the prevailing westerly winds to intercept

[127] Ibid., 126.
[128] Ibid., 345.
[129] Maury, *Maury's Sailing Directions*, 139.
[130] Semmes, *Memoirs of Service Afloat During the War Between the States*, 580.
[131] Ibid., 421-462.

vessels on the run to Europe, after which *Alabama* sailed south to the equator where Maury's advice was critical in a region where the doldrums could becalm a sailing vessel for days.

With Semmes' success, word was beginning to spread of *Alabama*'s depredations. *Harper's Weekly* published an engraving of the vessel when it was confirmed that the vessel "290" that had been observed under construction (it was the 290th keel laid at the Birkenhead dockyard of John Laird Sons), and that went to sea as the *Enrica*, was in fact fitted out with weapons and under sail as the "pirate" *Alabama*.[132] The editors urged caution (and didn't hurt sales) by exhorting, "No ship should sail out of port without this number of *Harper's Weekly*, in order that her captain may be able to recognize the pirate."[133] A (former) captain of one of Semmes' prizes reported to the *Harper's* readership the particulars of the vessel that "was built a few months since to prey upon our merchant navy…"[134] Semmes was reputed to wait until dark to torch the vessels he captured in order to lure innocents to the flame, so that the next morning vessels that had diverted from their journeys to answer the universal call to aid those in distress on the seas "find themselves under the guns of the *Alabama*, with the certainty that before another twenty-four hours they will share the fate of the ship they came to serve."[135]

Even with a steady drumbeat of reports in the press, to those far from America news still traveled slowly, and Semmes and *Alabama* were anything but. There were still many ships at sea without word or inkling that they were, in effect, prey. And Semmes was hunting. "We were at the "crossing" of the equator, "blazed" by Maury, and with the main topsail at the mast, were reviewing as it were, the commerce of the world. We were never out of the sight of ships. They were passing, by ones, and twos, and threes, in constant succession, wreathed in rain and mist, and presenting frequently the idea of a funeral procession. The honest traders were all there, except the most honest of them all – the Yankees – and they were a little afraid of the police. Still we managed to catch a rogue now and then."[136] North of the Tropic of Cancer, at another critical intersection of latitude and longitude under Maury's scheme of travel,

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132 Hearn, *Gray Raiders of the Sea: How Eight Confederate Warships Destroyed the Union's High Seas Commerce*, 153-155.
133 "The Pirate "Alabama"," *Harper's Weekly*, November 1, 1862, 690.
134 "The Pirate 'Alabama,' *Alias* '290.'", 699.
135 Ibid.
136 Semmes, *Memoirs of Service Afloat During the War Between the States*, 588.

Semmes found a similar scene, "…the lookout at the mast-head began to cry sails, until he reported as many as seven in sight at one time. They were all European bound, and were jogging along, in company, following Maury's blazes, like so many passengers on a highway. The *Alabama* stood like a toll-gate before them, and though we could not take toll of them, as they were all neutral, we made each traveler show us his passport…"[137] But even without taking prizes, *Alabama* was doing her part for the Confederacy, for the Union carrying trade was being swept from the sea and its vessels sold to foreign flags. Semmes gained intelligence from the mail and newspapers onboard his captures which confirmed his confidence in the strategy of waging *guerre de course*; after taking the vessel *Mina*, he learned from a Baltimore newspaper that New York merchants were feeling the impact. "The shipments of grain from this port during the past week have been almost entirely in foreign bottoms, the American flag being for the moment in disfavour in consequence of the raid of the rebel steamer Alabama!"[138] What is more, her actions continued to draw Union ships from the blockade; already hard-pressed relatively early in the war before her industries gained traction and ships came more steadily down the ways, the U.S. Navy was forced to station "ships in every ocean to look for her."[139]

Raphael Semmes was not the only Confederate Captain to take advantage of Maury's work. Lieutenant John Maffitt in *Florida* evaded the Union fleet blockading Mobile Bay and made the open sea in January of 1863. "Maury could not have laid out *Florida's* track any better had he been on board. Maffitt swept down the shipping lanes to the West Indies, doubled back, crossing the lanes between New York and Brazil, and sailed east into the lanes between the Cape of Good Hope and New York."[140] *Florida* put into Brest, France for repairs, and when she returned to the shipping lanes with a new commander, Lieutenant Charles Morris, she discovered fewer vessels of American registry that could be taken under international law. With intelligence from a few prisoners that were taken from some smaller captures, he learned that American ships were now avoiding Maury's lanes because of the efficacy of the Confederate raiders.[141] Sailing into U.S. waters *Florida* captured seven prizes in three days and then quickly turned south to avoid

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[137] Ibid., 582-583.
[138] Quoted in Raphael Semmes, *The Cruise of the Alabama and the Sumter* (London: Saunders Otley & Co., 1864), 144.
[139] Robinson, *Shark of the Confederacy: The Story of the CSS Alabama*, 3.
[140] Hearn, *Tracks in the Sea: Matthew Fontaine Maury and the Mapping of the Oceans*, 227.
[141] Ibid., 228.

the inevitable pursuit of federal warships. *Florida*'s career came to a conclusion when the Union warship *USS Wachusetts* violated Brazilian sovereignty by cutting the vessel out from anchorage in Bahia and bringing the captive back to Hampton Roads.[142] The last Confederate raider to terrorize Union shipping availed of Maury's charts as well. Lieutenant James Waddell sailed in *Shenandoah* to the far ends of the earth to find Yankee ships unawares and ripe for taking. Maury's *Whale Chart* reported whales in the Bering Sea, and *Shenandoah* journeyed from England by way of the Cape of Good Hope and around Australia into the North Pacific. By the time the ship reached the Yankee whaling fleet, the Civil War had ended. But whether Captain Waddell actually heard the news and chose to ignore it because of the prize money at stake, or because he could still strike a blow for the South while maintaining innocence of the news is still some subject of debate. What is not of issue is that Waddell and *Shenandoah* proceeded to annihilate the Yankee fleet. By the time Waddell 'heard' the news that the war was in fact over, *Shenandoah* had claimed 38 prizes and inflicted an estimated $1.3 million dollars in damage; twenty-four of these captures took place in one six-day period in the northern reaches of the Bering Sea.[143] When all was said and done, Confederate raiders had burned, bonded or sunk some 237 vessels and in doing had turned Maury's researches to an end he most likely never imagined some twenty years earlier when he began his efforts to make navigation safer and more efficient for the vessels of the world.[144]

On the Strength of One Link of the Cable, Dependeth the Might of the Chain

If Matthew Fontaine Maury's oceanographic investigations had only influenced the safety and efficiency of navigation at sea, and impacted national and international economic and security interests as reviewed above, his historical legacy would have been secure - even if damaged for a long period in his home country as a result of his decision to 'go South' in the Civil War. But at least one more critical result of Maury's work must be considered both in determining the measure of his contributions to ocean science and in assessing the way this affected national security. This was Maury's role in what was perhaps the greatest engineering feat of the 19th century, one that was accomplished over the course of a dozen years by

[142] Ibid.
[143] Ibid., 233-234; Murray Morgan, *Confederate Raider in the North Pacific: The Saga of the C.S.S. Shenandoah, 1864-65* (Pullman: Washington State University Press, 1995), 310-311.
[144] Hearn, *Tracks in the Sea: Matthew Fontaine Maury and the Mapping of the Oceans*, 234-237.

a relatively few number of people. It was an effort that tied the new world to the old, one that changed the nature of communications, economics, social and cultural institutions, and national security from that time forward.

The successful laying of the Transatlantic Telegraph ultimately had 'many fathers', but history accords to Cyrus Field the place of honor in this patrimonial pantheon. Through his indefatigable efforts throughout the successes achieved and failures suffered along the way, he remained the champion of the Cable. Field summarized the project and his role in it with characteristic humility and pith, "Maury furnished the brains, England gave the money, and I did the work."[145] To many minds such a daunting project was a fool's errand and an inexhaustible money sink, but this was mostly a matter of ignorance – of the mysteries of the 'lightning' of the telegraph and of the impenetrable depths of the mysterious deep ocean. The inventor of the electric telegraph, Samuel Finley Breese Morse would provide the *gravitas* to bolster the Cable 'Projectors' on the physics of the challenge; Lieutenant Maury, the marine savant who had - as Humboldt said - established a new science, was the definitive voice in answering the second question: whether it was plausible to attempt such a project in the ocean depths. On the advice and technical reputations of these two men, the Cable Projectors led by Cyrus Field succeeded in linking the continents by wire, with the attendant monumental changes that the Atlantic Cable would bring to the world.

The United States Congress recognized the initial success of Maury's *Wind and Current Charts* in the late 1840s, and with confidence that his fertile mind might lead to further innovations, invested in his ideas. Aside from the support Maury officially received through the budget of the National Observatory for the publication and distribution of his charts and *Sailing Directions*, Congress authorized the use of three naval vessels "for testing new routes, and perfecting the discoveries made by Lieutenant Maury in the course of his investigations of the winds and currents of the ocean."[146] Even before Maury received the use of these

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[145] Caskie, *Life and Letters of Matthew Fontaine Maury*, 118; Shafter, "What's in a Name: The *USS Maury*," 44.

[146] Quoted in S.P. Lee, *Report and Charts of the Cruise of the U.S. Brig Dolphin* (Washington: United States Senate, 1854), 2, Senate Document, No. 59; Maury, *The Physical Geography of the Sea*, 204. The Hydrographic Office was located at the National Observatory; the name was eventually changed to Naval

vessels, he was able to gather data from naval vessels that he was able to equip with adequate deep-sea sounding devices. The Secretary of the Navy interpreted the 1849 law liberally enough to allow such activities, and "under such auspices, it was decided to inaugurate a regular plan of deep-sea sounding for the American Navy."[147] Accordingly Maury received data from the *Albany* in the Gulf of Mexico, and from the *John Adams* and the *Saratoga* in the Atlantic, but these soundings were taken ancillary to the primary employment of the three warships.[148] The British *Challenger Expedition* is often claimed as the first voyage of oceanographic inquiry, but it can be firmly argued that the cruises of the *Taney* in 1849, the *Dolphin* from 1851 through 1853, and the 1856 cruise of the steamer *Arctic* rightly demonstrate this intent decades earlier, and with no small impact on the future of oceanography.[149] Through the role they played in revealing the secrets of the deep sea, these small vessels were the operational extension of Maury's ideas, the *in-situ* laboratories for testing his theories, and though these cruises are mostly forgotten they validated one-half of the question that might have remained a matter of speculation for decades to come: whether or not the 'lightning' of the electric telegraph could be made to traverse the hundreds of miles of ocean floor between America and Europe.

Lieutenant Maury's *Wind and Current Charts* provided insight into the mysteries of prevailing winds and currents, and in effect described the corresponding 'paths' through the seas that he recommended to mariners in his *Sailing Directions*. But Maury also realized that the researches into the mysteries of the seas were far from complete, and that while much was being learned about the surface of the oceans, virtually nothing was really known about the deep sea. Beyond the practical aspects of his work, Maury was preoccupied with the scientific understanding of the wonders the reams of observational data revealed to him as abstract logs arrived at the Observatory. What effect did the shape of the ocean bottom have on currents? What would the third dimension of the ocean – the physical properties of the water column -

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Observatory and is often used interchangeably; the organization was the expansion of the Bureau of Charts and Instruments that Maury grew from a repository of logs and instruments into a first class astronomical observatory, and later a center of incipient oceanographic research.

[147] Matthew Fontaine Maury, *The Physical Geography of the Sea*, Sixth ed. (New York: Harper & Brothers, 1859), 375-376.

[148] Ibid., 376.

[149] The story of these cruises and tables showing the data they collected are integrated into Maury's discussion in the chapters "The Depths of the Ocean", "The Basin of the Atlantic", and "Submarine Telegraphy" in Maury, *Maury's Sailing Directions*, 113-199.

reveal to Maury about these features? Was the deep sea floor an unremarkable plain smoothed by the dust and silt that settled into its depths, or was it contoured and textured like the continents? There had been a few soundings of the deep ocean - some of which were of dubious validity - that showed it was miles deep over some of its extent. But as can be seen by looking at nautical charts of the day, very little was known of the contours of the sea-bottom beyond the nearshore region that was sounded regularly by sailors to keep their ships clear of reefs and shoals as they approached land.[150] There was only one way to find out, and that was to gather data from the deep sea and the seafloor, and this was not something Maury could accomplish in the same fashion as he did with the abstract logs, for sailing ships of the day (even naval vessels) lacked the equipment to carry out his experiments. And taking a deep sea sounding or attempting a sample was an hours-long event, not something merchant vessels were likely to delay their passage to conduct, and an out-of-the-normal evolution for naval vessels already busy with business at hand. What is more, the abstract logs were successful partly because they were designed to ask for information that prudent mariners would by and large observe as a matter of course; the log merely gave him a place and incentive to record his observations. For the type of information Maury needed to reveal the secrets of the sea, a dedicated cruise of investigation was required.

The first vessel that Maury dispatched to gather information and test out his theories taught him more in failure than from success. The *Taney* was not a good sea keeper and it quickly became evident that a more stable platform was required to collect data.[151] More than this, a new method was required; the old techniques of sounding the ocean depths were of questionable value for a number of technical reasons once the deep sea became the object of interest rather than more shallow coastal regions. Recovering a sample from the ocean floor was also no mean feat. Maury and the lieutenants and passed midshipman who worked with him at the Naval Observatory invented a number of methods to overcome this challenge; the most successful was devised by a passed midshipman, John Brooke, and became known as Brooke's Deep-Sea Sounding Apparatus. Its design was remarkably simple: a cannon ball with a hole drilled through the

[150] Ibid., 113-179; Maury, *The Physical Geography of the Sea*, 375-378. In the chapter entitled "The Depths of the Ocean" of Maury's final edition of the *Sailing Directions*, he provides details about his interest in the sea floor, one that is intimately tied with another of his interests - and the name of a follow-on chapter - "Submarine Telegraphy."
[151] Maury, *The Physical Geography of the Sea*, 375; Williams, *Matthew Fontaine Maury: Scientist of the Sea*, 228.

center was the weight that helped ensure a vertical drop (so that ocean currents would not carry the device horizontally away from the research vessel) and to help signal through the tension on the suspending line when the bottom was encountered. Through the hole was passed a rod with a hollowed end and some tallow to collect a seafloor sample. An ingenious rig was designed to release the cannon ball when the contraption hit the sea floor, so that the hollowed out pipe could be extracted and hauled up with little resistance.[152] The brig *Dolphin* was next assigned to Maury to replace the inefficient *Taney*, and on its third cruise in 1853 it took with it to sea Brooke's Deep-Sea Sounding Apparatus. Using the Brooke device *Dolphin* recovered a sample from the sea floor 2800 fathoms – almost 17,000 feet – down; the first *deep-sea* sample ever collected was reported as yellowish-white chalky clay.[153]

The significance of *Dolphin*'s successful investigations using Brooke's Deep-Sea Sounding Apparatus on her third investigatory cruise for Maury is not patently evident beyond the immediate fact that scientific inquiry had pushed the investigative envelope where it had never gone before. But this was a very significant cruise, and the samples recovered by *Dolphin* equally significant because of what would evolve from Maury's analysis of the data that reached him at the Naval Observatory.[154] To begin with, *Dolphin* had sailed between Cape Henry, Virginia and Rockall, Ireland, then continued south to Fayal in the Azores Islands, to the Cape Verde Islands, and along 25 degrees north latitude to the West Indies. Together with the data from two earlier cruises that *Dolphin* conducted south of this region, and what data were available from *Taney*'s single expedition and the relatively few yet significant soundings supplied by other Navy vessels, Maury was able to construct the first contoured bathymetric chart of the Atlantic Ocean basin.

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152 Maury, *The Physical Geography of the Sea*, 205-207; Maury, *Maury's Sailing Directions*, 120-121.

153 Edward Leon Towle, "Science, Commerce and the Navy on the Seafaring Frontier (1842-1861) - The Role of Lieutenant M.F. Maury and the U.S. Naval Hydrographic Office in Naval Exploration, Commercial Expansion, and Oceanography before the Civil War" (Doctoral Dissertation, University of Rochester, 1966), 285.

154 It is interesting to note that Maury was not in effect a 'seagoing' oceanographer. His days aboard Navy ships ended with his accident and he made most of his subsequent discoveries from the original logs he found at the Depot of Charts and Instruments, through the data returned in the abstract logs he designed for dissemination to ships, and from data collected by those he sent to sea on dedicated research cruises. Though often analyses of data collected at sea are done ashore – the *Challenger* Expedition results took more than twenty years to analyze and publish – the perception of oceanography is that it is largely a 'hands on' science, conducted by scientists who go to sea. Nevertheless, it is Maury's name that is associated with the discoveries made through the researches described herein. It is an interesting foreshadowing of the modern science in which many oceanographers do not conduct their research at sea, as remote sensing techniques have made research oceanography possible far from the ocean realm.

With some artistic license in interpolating the sparse data over such a broad region, Maury was able to include depth contours at 1,000 fathom intervals down to 4,000 fathoms.[155]

Though not published in similar fashion, water column measurements were made at the locations of the soundings, providing data in *three dimensions* - not just in the sense of depth, but with information descriptive of the physical properties of the fluid column. It is also of subtle but important note that Maury considered this view of the ocean floor to be 'orographic' in nature. Orography is a branch of the geological sciences that studies mountains…a direct nod to Maury's understanding that the unseen depths were likely contoured as were the landmasses – with mountains and features as dramatic as cliffs and canyons that were not resolvable at the sampling interval represented by the soundings he had with which to work. Given that this Atlantic chart was a basin-wide interpretation of the ocean depths and not some coast or harbor where the information gathering might be ascribed to the need for inshore navigation, it is difficult to see how this effort – however crude in resolution its depth contours may appear – would not be seen as a significant enough to merit Maury's work at the least an honest candidate for the 'beginnings of oceanography as a science' laurels.

Together with the seafloor samples gathered in the cupped rod of the Brooke device, Maury was not only able to say something about the *depth* of the ocean, but also about the composition of the seafloor. At first glance the chalky white substance recovered by *Dolphin* was assumed to be clay, but Maury sent it for analysis. He received an interesting report in return from Professor Bailey at West Point, "I was greatly delighted to find that *all* these deep sea soundings are filled with microscopic shells; not a particle of sand or gravel exists in them."[156] Maury concluded that since these microscopic shells were unabraded, and no sand or gravel was mixed in them by the scouring action of deep sea currents, that the seafloor where these samples were taken was must be relatively quiet - an undisturbed ocean bottom where the tiny skeletons of sea life rained down in a slow drift over millennia to form a soft layer of chalky calcareous and silicious

[155] Plate XI of both *The Physical Geography of the Sea* and *Maury's Sailing Directions* is this first orographic interpretation of the Atlantic Basin. The soundings of both survey vessels, *Taney* and *Dolphin* can be seen individually annotated on this chart.
[156] Quoted in Maury, *Maury's Sailing Directions*, 168.

ooze.[157] The particular samples of interest sent to the lab at West Point had come from the section of *Dolphin*'s cruise that had supplied Maury with some intriguing soundings. Where other sections across the Atlantic indicated an uneven sea bottom, with underwater peaks and valleys, this northern track between Newfoundland and Ireland indicated a relatively shallow and flat plain. Lieutenant Maury had not blindly requested soundings along this track – it represented the shortest distance between Europe and the Americas. The results of *Dolphin*'s sounding expedition and the analysis of the samples by Professor Bailey fired Maury's imagination; whether or not he intended the name to become official, from his description this region of the ocean floor quickly became known as the Telegraph Plateau.[158]

Literally as Maury was writing to the Secretary of the Navy to report the findings of the *Taney* and *Dolphin* expeditions, together with his interpretations of the results and the new three-dimensional picture of the Atlantic that was emerging, a letter arrived at the Naval Observatory with an inquiry related to the ocean floor of the North Atlantic between America and Europe. "Singularly enough," began Maury's reply, "just as I received you letter, I was closing one to the Secretary of the Navy on the same subject."[159] The letter that arrived at the Observatory was one of two sent by the wealthy New York businessman Cyrus Field to determine the feasibility of an idea he wished to pursue; the other letter was addressed to Professor Samuel Morse, the inventor of the telegraph.[160] Field had been approached in January, 1854 about the possibility of bankrolling a submarine telegraph from Newfoundland to the United States. Since Newfoundland was the closest point of North America to Europe, the proposal sought to shorten the time it took for news to travel from Europe to the United States by passing the news along once it had been received by steam vessels crossing the Atlantic along the shortest possible route. Field was struck by a still

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[157] Maury, *The Physical Geography of the Sea*, 210-216; Maury, *Maury's Sailing Directions*, 170-175. Calcium carbonate and silica are the two structural building blocks for diatoms, foraminifera and radiolarians – the microscopic life that forms the basis of the marine food chain. As these organisms die and sink to the bottom of the sea, natural decomposition leaves the hard microscopic skeletons which form such fine silt that they became known as 'oozes.'
[158] Maury, *Maury's Sailing Directions*, 180.
[159] As quoted in Henry M. Field, *The Story of the Atlantic Telegraph* (New York: Charles Scribner's Sons, 1893).
[160] Isabella Field Judson, *Cyrus W. Field: His Life and Work* (New York: Harper & Brothers Publishers, 1896), 61.

bolder idea, "It was thus studying the globe that the idea first occurred to him, that the telegraph might be carried further still, and be made to span the Atlantic Ocean."[161]

Two primary issues presented themselves: was it possible to stretch a cable across the deep unknown of the Atlantic; and would the little understood properties of electricity be capable to transmit messages over a cable more than 1,500 miles in length?[162] The second question was addressed to Professor Morse, who had first successfully experimented with an underwater cable in New York Harbor in 1843, and who was familiar with the success by two Britons in laying a submarine cable across the Channel between Dover and Calais in 1851. In reply, Morse quoted to Field from a letter he had written at the time of his underwater experiment about the ability of electricity to communicate over great distances, "The practical inference from this law is, that a telegraphic communication on the electro-magnetic plan may with certainty be established across the Atlantic Ocean! Startling as this may now seem, I am confident the time will come when this project will be realized."[163]

In his reply to Cyrus Field, Matthew Fontaine Maury was as confident as Professor Morse that the deed could be accomplished. He included a copy of his letter to the Secretary of the Navy in which he detailed the results of the studies based upon the cruises of *Taney* and *Dolphin*:

> *"This line of deep-sea soundings [from Newfoundland to Ireland] seems to be decisive of the question of practicability of a submarine telegraph between the two continents, in so far as the bottom of the deep sea is concerned. From Newfoundland to Ireland, the distance between the nearest points is about sixteen hundred miles; and the bottom of the sea between the two places is a plateau, which seems to have been placed there especially for the purpose of holding the wires of a submarine telegraph, and of keeping them out of harm's way. It is neither too deep nor too shallow; yet it is so deep that the wires but once landed, will remain for ever beyond the reach of vessels' anchors, icebergs, and drifts of any kind, and so shallow, that the wires may be readily lodged upon the bottom. The depth of this plateau is quite regular, gradually increasing from the shores of Newfoundland to the depth of from fifteen hundred to two thousand fathoms, as you approach the other side."* [164]

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[161] Field, *The Story of the Atlantic Telegraph*, 16.
[162] Ibid., 17.
[163] Quoted in Ibid., 21-22. Morse's letter in its entirety was also reprinted in a newspaper of the day upon the initial success of the telegraph. Under the title "A Remarkable Prediction," Professor Morse's letter to the Honorable John C. Spencer, United States Secretary of the Treasury, can be read on page two of the August 13, 1858 edition of the *Boston Post*. As an interesting aside, in a column that reports the latest laws enacted by the U.S. Congress on the back page of this edition of the *Boston Post*, a small notice appears reporting the assent of Congress for "Commander M.F. Maury…to accept the great gold medal of the arts and sciences recently presented to him by his Majesty, the Emperor of Austria."
[164] Quoted in Maury, *The Physical Geography of the Sea*, 378-379.

Maury emphasized his limits of knowledge in making the recommendation of the cable as being only an assessment of the matter of the deep seabed. He noted that he had not yet considered, "…the question as to the possibility of finding *a time calm enough, the sea smooth enough, a wire long enough, a ship big enough*, to lay a coil of wire sixteen hundred miles in length."[original emphasis][165] However when the time came that Cyrus Field had gathered a wire long enough and ships large enough to do the job, Maury studied the region and made his recommendation as to the best weeks in the summer to undergo the effort, and plotted a great circle track for the ships to follow to effect the shortest distance when balanced with the safest contours of bathymetry as he knew them.

> *"Perhaps it would be wise for the steamers not to join cables until after the 20th of July. I think between that time and the 10th of August the state of both sea and air is usually in the most favorable condition possible; and that is the time which my investigations indicate as the most favorable for laying down the wire. I recommend it and wish you good-luck."*[166]

Following Maury's advice, the great project was begun in the summer of 1857.

The story hereafter of the *laying* of the Atlantic Cable is one of perseverance on the part of Cyrus Field and others and faith that the science and engineering of the times were up to the challenge. After failing in 1857, the cable was successfully laid – to great acclaim – in 1858, only to last about a month during which time only a few hundred messages were successfully passed. After much analysis, engineering, and politicking the project was undertaken again in 1865 and successfully completed in 1866. In the intervening years speculation ran high that it could not be completed, but Maury and Field and the engineers were steadfast in their convictions. Maury even went so far to demonstrate his confidence to write that as far as the conditions on the sea bottom were concerned – some of the speculation was that the failed cable was abraded and cut, possibly on an undersea mountain peak – that only a simple wire coated in gutta percha for insulation would suffice instead of the armored cable which was used and that allowed that much more measure of assurance.[167]

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[165] Quoted in Field, *The Story of the Atlantic Telegraph*, 20.
[166] Quoted in Judson, *Cyrus W. Field: His Life and Work*, 75.
[167] "Lieut. Maury on the Atlantic Cable," *Lowell Journal and Courier*, October 12, 1859, 2; Maury, *Maury's Sailing Directions*, 180-182.

But the story of the Cable is not merely one of science and engineering as great as it was. It is a textured story of the ambiguous relationship of a great power with the nation it sired. Although the Atlantic Cable was the conduit of news and information from the Continent to the New World and *vice versa* – as innocuous as that may seem - from the very beginning it was a matter of debate about national security in both England and the United States. A study of the map and brief reference back to Maury's note to the Secretary of the Navy illuminate the physical realities that made security an immediate concern: the origin and endpoint of the Cable, whichever way one wished to look across the Atlantic was in the hands of the British Empire. From Valentia, Ireland to Trinity Bay, Newfoundland, the Cable was not once in American waters. With an American as its main advocate and entrepreneurial spirit, and the necessity of sharing the risk of such a venture between the governments and investors of the two nations, the matter of the ownership and control of the Cable was one of considerable debate, at least on the side of the Atlantic where the vulnerability was felt most keenly.

It is informative to see the manner in which the Cable was perceived by the American public to begin to understand why it immediately represented a matter of security for the fledgling nation. Although the American people shared familial and cultural ties with England, there was still a good deal of mistrust for the British Government from which the United States had separated itself within the living memory of some of its elder members. The American people and their elected officials also remembered the War of 1812, a conflict which started in part over the lack of respect shown to American sovereignty and the impressment of sailors from American flagged vessels by English warships overhauling them at sea, and one in which Great Britain had burned the federal city of Washington. Controversy with Great Britain over the Oregon Territory was a diplomatically sensitive and fluid situation; and a subject of immediate concern at the time of the efforts to gain approval to proceed with the Cable project was the questionable British practice of boarding vessels on the high seas in its zealous efforts to end the slave trade – something fearfully reminiscent of its impunity with regards to impressment of seamen in 1812.[168] The idea of supporting a project that would extend command and control of still formidable British fleets across the

[168] "The Dispute With Great Britain," *Harper's Weekly*, July 3, 1858, 422; "End of the Anglo-American Difficulty," *Harper's Weekly*, July 31, 1858, 487; "The New Dispute With England," *Harper's Weekly*, September 17, 1859, 599; "Our Efforts Against the Slave Trade," *The Springfield Weekly Republican*, May 29, 1858, 2.

ocean was not insignificant. "There were some who felt that in this submarine cable England was literally crawling under the sea to get some advantage over the United States!"[169]

The subject of British control of the Cable and its implications in time of war remained a matter of debate in the U.S. Congress; the formidable debater Senator Stephen Douglas addressed these concerns, "Our policy is essentially a policy of peace. We want peace with the whole world, above all other considerations. There never has been a time in the history of this republic, when peace was more essential to our prosperity, to our advancement, to our progress, that it is now. We have made great progress since the last war with Great Britain. Twenty-five years more of peace will put us far in advance of any other nation on this earth."[170] But Douglas also held out the brass knuckles in a velvet glove, "I am willing to vote for this bill as a peace measure, as a commercial measure – but not as a war measure; and when war comes, let us rely on our power and ability to take this end of the wire, and keep it."[171] Though not a member of Congress, and perhaps not even in a diplomatic or bureaucratic sense the right person to whom to address such questions, Lieutenant Maury was also brought into the congressional debate. In a letter to Maury, a member of the House of Representatives posed some pointed questions, "Is there a point, *under our flag*, which would answer for the western terminus? If not, what are the obstructions? What influence would it have in a military point of view?"[172]

Maury answered this query from Capitol Hill by informing the representative that the shortest distance from England to the United States without passing through British territory in the Western Atlantic was some 3,000 miles, almost twice the distance of the proposed Atlantic Cable from Ireland to Newfoundland. In addition, such a course would bring Portuguese sovereignty into question because of the route's proximity to the Azores. What is more, the wire would have to traverse what Maury had determined to be the deepest section of the Atlantic, as well as a volcanic region with its attendant dangers to such a fragile cord. Maury argued that the Cable was a joint endeavor between the United States and England, and that it

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[169] Field, *The Story of the Atlantic Telegraph*, 102.
[170] Ibid., 109.
[171] Ibid., 107.
[172] Quoted in Charles F. Briggs and Augustus Maverick, *The Story of the Atlantic Telegraph, and a History of the Great Atlantic Cable* (New York: Rudd & Carleton, 1858), 224.

would be mutually harmful should the line be damaged or destroyed by either side. With connectivity between the two nations he saw the likelihood of war between them diminished, and he pointed out that during a recent war on the Continent, "…vengeful though it was, was not savage enough to break a single line of telegraphic wire." The Cable was something greater than a matter of simple tactical usage…it embodied the advancement of ideals. He recounted the actions of the French king at war with Britain during the time of Captain Cook's South Seas explorations, and his response to entreaties to not destroy the expedition records should Cook's vessels be captured, "I war not against science." He called attention to the Brussels Maritime Conference, and the agreement to hold the abstract logs "sacred" even if a vessel should be taken by a belligerent. From a more practical standpoint, Maury theorized that should war with England come when there was no transatlantic cable in existence, alone that nation could succeed in a matter of less than a year with no moral ambiguities arising as they would under a joint venture. He summed up his assessment of both the prospects for the successful completion of the undertaking, and the proposed route from Ireland to Newfoundland, "Submarine Telegraphy is in its infancy, but it is the act of making the stride of a full-grown giant; and no problem can to my mind be more satisfactorily demonstrated than is the practicability of readily, and almost without risk, laying the wire from land to land upon this telegraphic plateau of the Atlantic."[173]

Outside the halls of the U.S. Congress, the American public's view was not necessarily as dire as those in Congress that opposed the undertaking. The Cable was seen as an opportunity to strengthen bonds between the two nations, to avoid miscalculations based upon faulty information or news that was too late to prevent a situation from spiraling out of control. It was not overlooked that the Battle of New Orleans during the War of 1812 – although an American victory and perhaps the political springboard for Andrew Jackson howsoever that might be viewed in American politics – occurred some fifteen days after the Treaty of Paris had determined a cessation of hostilities. Fifteen days was at that time just about the fastest time that news might have traveled across the Atlantic with this information. In the contemporary papers,

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[173] Excerpted from a letter dated December 31, 1856 from Matthew Fontaine Maury to the Honorable C.C. Chafee printed in its entirety in Appendix II of Ibid., 224-228.

editors and letter writers instead waxed philosophic about the potential for closer ties with the Continent.[174] "Never has typography been so excited," burbled one editorial writer contemplating headlines adequate to such monumental news (perhaps this was also his excuse for not succeeding…).[175] Not a few of these were messages about the possibility of a Kantian notion of *perpetual peace* when the cable was in place: "The heart of the world beat under the sea."[176] An American observer present in England marveled at the sight of the *USS Niagara* and *HMS Agamemnon* just after receiving the sections of the cable that would be joined in the middle of the Atlantic and run simultaneously to the shore sites, "To see these two mighty ships of war, with their consorts, lying side by side, not with guns run out, but engaged in a mission of peace, seemed indeed an omen of the good time coming, when nations shall learn war no more."[177] Another marveled as he watched the cable being transferred aboard ship that, "…that little iron cord, about an inch in diameter…is a thing of world-wide fame – a thing which may influence the life of whole nations; nay, which may affect the march of civilization."[178]

The front page illustration of the *Harper's Weekly* of August 14, 1858, the edition that trumpeted the news of the success of the telegraph, was of two angels linked hand in hand and extending an olive branch before them as they floated above the ocean floor. The Cable can be seen beneath the angels' feet, and strewn all around are the wrecked instruments of war: cannon and shot, pistols and swords, rifles with bayonets, and somewhat luridly human bones clearly shot through with bullet holes. And this celebration of the potential for peace at a time when these two nations were not at war![179] The following two ditties of American and British authorship respectively appeared in the *Harper's Weekly* of September 4, 1858 – ironically after the Telegraph had failed but before it was widely known; composed to the tunes of popular contemporary songs, they indicate these hopeful sentiments:

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[174] "The Atlantic Telegraph," *The Springfield Weekly Republican*, August 14, 1858, 2; "Effects of the Atlantic Telegraph," *Harper's Weekly*, August 14, 1858, 514; "The Great Event of the Age! The Atlantic Cable Laid and Electric Signals Passing Through It.," *The Springfield Weekly Republican*, August 14, 1858, 3; "The Ocean Telegraph," *Harper's Weekly*, August 14, 1858, 515; "The Ocean Telegraph Expedition," *New York Daily Tribune*, August 27, 1858, 6; "Renewal of the Telegraph Experiment," *Harper's Weekly*, July 31, 1858, 482.
[175] "The Jubilee," *Harper's Weekly*, August 28, 1858, 547.
[176] Field, *The Story of the Atlantic Telegraph*, 373; "The President's Reply," *Harper's Weekly*, August 28, 1858, 550.
[177] Field, *The Story of the Atlantic Telegraph*, 153.
[178] Quoted in Ibid., 262.
[179] "The Atlantic Telegraph," *Harper's Weekly*, August 14, 1858, 513.

The Official Ode on the Cable
By Mrs. Ann S. Stephens

Oh, say not the old times were brighter than these,
When banners were torn from the warriors that bore them!
Oh, say not the ocean, the storm, or the breeze,
Are freest or proudest when war thunders o'er them!
For the battle's red light grows pale to the sight,
When the pen wields its power, or thought feels its might:
Now mind reigns triumphant where slaughter has been,
Oh, God bless our President! God save the Queen!

Let the joy of the world in rich harmony rise,
Let the sword keep its sheath, and the cannon its thunder;
Now intellect reigneth from the earth to the skies,
And science links nations that war shall not sunder.
Where the mermaids still weep, and the pearls lie asleep,
Thought flashes in fire through the fathomless deep;
Now mind reigns triumphant where slaughter has been,
Oh, God bless our President! God save the Queen!

When the sunset of yesterday flooded the west,
Our old mother country lay far in the distance;
But the lightning has struck! – we are close to her breast –
That beautiful land that first gave us existence!
We feel, with a start, the quick pulse of her heart –
And the mother and child are no longer apart!
For mind reigns triumphant where slaughter has been,
Oh, God bless our President! God save the Queen!

The blood that was kindred throbs proudly once more,
And the glow of our joy fills the depths of the ocean;
It thrills through the waves, and it sings on the shore,
Till the globe, to its poles, feels the holy commotion.
Let us join in our might, and be earnest for light;
Where the Saxon blood burns, let it strive for the right;
For mind reigns triumphant where slaughter has been,
Oh, God bless our President! God save the Queen!

The Anglo-Saxon Twins Connected by the Atlantic Telegraph
By Anonymous

Success at last sits, like a crown, upon our work gigantic;
Behold the Telegraph laid down beneath the broad Atlantic.
Yankee doodle, etc.

Accomplished is the mighty job, in spite of wind and weather;
So *Jonathan*, we now shall throb with sympathy together.
Yankee doodle, etc.

The two great nations not in chains are now as one connected,
Whereby the cause of Freedom gains, for 'twill be more respected.
Yankee doodle, etc.

United, Brother *Jonathan*, in firm amalgamation,
I guess we Anglo-Saxons can, if need be, whip creation.
Yankee doodle, etc.

The odds are very much increased, by our more close communion,
Against the Soldier and the Priest, with Despots linked in union.
Yankee doodle, etc.

Let but our forces be combined, and we'll preserve from fetters
A no small some of human mind, in science and in letters.
Yankee doodle, etc.

Free Press, which every bigot hates, free utterance of opinions,
Shall live in the United States, and British Queen's dominions.
Yankee doodle, etc.

May talk of lightning slick as grease, discussions shortly finish,
And every chance of broken peace to less than naught diminish.
Yankee doodle, etc.

Now every squabble we have had is pretty nigh forgotten,
So let us set to work like mad, and deal in corn and cotton.
Yankee doodle, etc.

Two thousand miles beneath the sea, if you're inclined as I am,
That wire will draw close you and me as those famed twins of Siam.
Yankee doodle, etc.

So let United freemen's cheers drive all tyrants frantic,
The Telegraph, as each one hears, has spanned the great Atlantic.
Yankee doodle, etc.[180]

The world waited to hear what the first official messages passed via the 'lightning' would say. By agreement, Queen Victoria was to send the first and President Buchanan was then to honor her with a reply. Both leaders spoke to the great possibilities that awaited this transatlantic link, but the relations between the two nations and the tensions that had underlain their previous decades of interaction were not far from the surface. After congratulating the president, the Queen went on to express her hope that the Cable would, "…prove an additional link between the nations whose friendship is founded upon their common interest and reciprocal esteem."[181] President Buchanan thanked Queen Victoria for her kind remarks, and regaled the Cable as, "…a triumph more glorious, because far more useful to mankind, than was ever won by conqueror on the field of battle." Seemingly unable to stray from this theme and the underlying concerns

[180] "The Anglo-Saxon Twins," *Harper's Weekly*, September 4, 1858, 563; Ann Stephens, "The Official Ode on the Cable," *Harper's Weekly*, September 4, 1858, 562. "The Anglo-Saxon Twins" was attributed by Harper's to *Punch*, the famous British satirical newspaper of the time.
[181] "The Queen's Message," *Harper's Weekly*, August 28, 1858, 550.

of the United States with regards to the use of the Cable in time of war, President Buchanan continued by expressing his hope that the Cable would be, "…a bond of perpetual peace and friendship between kindred nations, and an instrument destined by Divine Providence to diffuse religion, civilization, liberty and law throughout the world." Then, with what some would say was a lack of tact at such a monumental occasion the President declared, "In this view will not all nations of Christendom spontaneously unite in the declaration that it shall be forever neutral, and that its communications shall be held sacred in passing to their places of destination even in the midst of hostilities."[182] Whether just to reinforce the United States determination to preclude British domination of the transatlantic information link, or out of naïveté that such an appeal would be heeded, Buchanan's message comes across as something less than…fitting for the enormity of the occasion.

The first message after the perfunctory salutations of the national leaders was somewhat auspiciously one of peace: a treaty had been signed ending the hostilities between the combined governments of England and France with the Chinese government over trade and embassy rights.[183] Also reported, however, was that a mutiny in Bombay against the British was being rapidly put down - news to be sure, but news that approached the level of military intelligence as word was passed subsequently that troops being readied in Canada to reinforce the Indian regiments were no longer needed, canceling a deployment that would have cost the Crown between £50,000 and £60,000, an amount that represented about 15 per cent of the capital investment in the Cable for this one instance alone.[184] Incidentally – if unintentionally – it also clearly demonstrated the Cable's potential for long-distance command and control of military assets, one of the chief concerns of those in America who opposed the project. Merely by passing on important news, decisions of military consequence might be made – even if cables between military outposts never 'lit up'

[182] "The President's Reply," 550. Disdain for the President's somewhat tactical if diplomatically tactless reply was editorialized in this same edition of *Harper's*: "The First Transatlantic Messages," *Harper's Weekly*, August 28, 1858, 546; "The Messages," *Harper's Weekly*, August 28, 1858, 547.
[183] "The First News Dispatch By The Ocean Telegraph," *New York Tribune*, August 27, 1858, 5.
[184] Ibid; John Steele Gordon, *A Thread Across the Ocean: The Historic Story of the Transatlantic Cable* (New York: Walker & Company, 2002), 141.

the wires. Eventually time would prove this out; undersea cables became indispensable links for the British government in maintaining her far-flung empire, and a vital matter of national security.[185]

There is no telling for certain how the existence of a working transatlantic cable might have affected the run-up to the American Civil War or the progress of that conflict once begun. It is evident that it would have played a role. The *Trent Affair*, an incident wherein an overzealous Union Navy gunboat captain removed from a Royal Mail vessel two Confederate envoys in a rather blatant overstep of international law, very nearly led to hostilities with Great Britain. The *London Times* put it bluntly: “We nearly went to war with America because we had not a telegraph across the Atlantic.”[186] The diplomatic affront was eventually smoothed over, but the time delay for information traveling back and forth across the Atlantic stoked anger on both sides as the story unfolded. At a time when the Confederacy desperately wished for a European ally like England, and the Union could ill afford that possibility, the situation was gravely serious. Similarly, with the advantage of some twenty days for news to make the round trip, the Confederate agents in England that were outfitting raiders – men like Matthew Fontaine Maury –were facilitated in getting vessels to sea before intelligence could verify their true intent and diplomatic entreaties made by the United States Government. This convenient means of looking the other way may have been to Great Britain’s advantage as discussed earlier with respect to overcoming the American carrying trade, but sentiment against England ran strong on the other side of the Atlantic. Reporting on the depredations of *Alabama* as news trickled in from overseas, the New York papers made it clear how they felt about British complicity, “She is a British vessel, with a British register, is manned by a British crew, and is commanded by the infamous Semmes…but nothing can be known of her destination, for Semmes, like other pirates, is not responsible to any one except the British Government, for his vessel is British.”[187]

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[185] Edward S. May, *Imperial Defence* (London: Swan Sonnenschein & Co. Limited, 1903). In the chapter “The Great Cable Communications of the Empire,” May describes the reliance on undersea cables to relay vital intelligence for the administration and defense of the British Empire. Almost every British possession is linked via submarine cable, and interestingly no cable spans Canada. News from British Columbia traveled via Pacific, Indian Ocean, Red Sea, Mediterranean, and Eastern Atlantic Cables to pass information to the Home Island.

[186] Quoted in Field, *The Story of the Atlantic Telegraph*, 235. A discussion of the *Trent Affair* and the need for transatlantic communications may be found in Gillian Cookson, *The Cable: The Wire That Changed The World* (Stroud: Tempus Publishing Limited, 2003), 125-126, 128.

[187] "The British Pirate "290," Alias the *Alabama*, and Her Victims," *New York Tribune*, October 29, 1862, 1.

The lack of telegraphic connections across the Atlantic was a complex issue for the Confederacy. Were the British able to establish command and control of her fleets and armies of her Western Atlantic possessions, she might well be able to retake possession of her colonies weakened by war as they were. The *Richmond Enquirer* assessed the North's continued efforts with England to complete the cable, "…that stupid and blinded people are actually subscribing money to forge a chain for its own limbs…let war break out between England and the Yankees, and the Atlantic Cable will be about as neutral as the Royal artillery and the Channel fleet and the Horse Guards."[188] Were not other European countries able to retake their possessions in the Americas once weakened by ineffective governments and internal strife? Such was the case in Mexico save that the European power was France instead of Spain by manner of an earlier coup. Was not England plying both sides of the American conflict to her own advantage to ripen the situation? "Hence the highly virtuous and conscientious British neutrality, and the warm words of cheer and encouragement bestowed by turn upon each belligerent. Hence the persistent policy of non-recognition, while enthusiastic English writers assure the Confederates that they can never be conquered, and that reunion is impossible; and others no less warmly hound on the Federals to a vigorous prosecution of the war, and tell them that they have the civilized world with them as champions of 'human freedom.'"[189]

This policy of playing both sides until they weakened would continue until the Cable was laid at which point, "…a word of command whispered at the Horse Guards will then reach American shores about three hours earlier on the same day. The moment the cable is laid both ends of it will be guarded by impregnable fortresses, mounted with the longest range guns. England will then have cast her fetters over the hands of the Yankee nation, and can snap the lock."[190] Where this might have served the aims of the South in defeating the North, it also made one careful what they wished for. If Britain came in on the side of the South as her envoys sought, the end result might be re-established Crown control on the northern frontier of the Confederacy. "Give us ignorant and semi-barbarous enemies to deal with, if we must have enemies;

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[188] As reported in the "News From The South" column of a California newspaper: "The Atlantic Cable Destined to Re-Establish English Supremacy Over the Whole United States," *Sacramento Daily Union*, December 7, 1863, 8.
[189] Ibid.
[190] Ibid.

and on the north bank of the Potomac, for ages to come, we can look for nothing else but enemies. Therefore we strongly incline to hope that this time again the Atlantic cable will break and fail."[191] With the example of the *Trent Affair* and the animosity between the North and England over issues such as the Confederate raiders, it was evident that with no Cable there existed the possibility that war could result between England and the Union; and then there was the contrary logic that the Cable would enable Britain to enter into hostilities and retake (at least her Northern) possessions on this side of the Atlantic. Ignorance and conspiracy theory make strange bedfellows, but either way it was plain that telegraphic communications – or rather possibly the lack thereof – made a difference in the prosecution of the American Civil War, at least from an American perspective.

The impact of the Atlantic Telegraph upon the world would take volumes to recount. It changed the nature of international transactions, virtually ending the wild speculations of currency arbitrage and the lottery-like trade in commodities where shipments sent in the ignorance of prevailing rates at their destinations might encounter windfall profits or pennies on the dollar.[192] The social and cultural flows of information that crossed the wire reached into all aspects of society. With her ascendant power, America would not long be able to live in splendid isolation; the Cable bound the nation back to the Continent from which she was conceived and that continued to send its 'huddled masses' to expand American frontiers, and to populate its cities and the factories of a rapidly industrializing economy. And the Cable demonstrated immediately the power it possessed for martial applications: the ability to relay important political information that might bear on diplomatic negotiations and confrontations; the ability to marshal forces and to direct their movements from a central command; a lifeline of communications to far distant allies. If information is power, then the Cable represented newfound leverage that nations had to quickly come to grips with. The British Empire, spanning the globe such that the 'sun never set' on its dominions was the archetype power to avail of the utility of the Cable. The day after news reached London that the

[191] Ibid.
[192] Speculation on these very subjects can be found in the press of the day, with foresight that is indeed enviable. One particularly insightful column that ponders the effects on social and financial structures, as well as security and diplomacy was published under the headline "Effects of the Atlantic Cable" in the August 14, 1858 issue of *Harper's Weekly* that trumpeted the news of the successful laying of the first Atlantic Cable. Although these speculations did not bear fruit for some eight years until the 1866 Cable proved an enduring triumph, they were no less on the mark at that point in time.

Cable had been landed, the *Times* commented, "More was done yesterday for the consolidation of our empire, than the wisdom of our statesmen, the liberality of our Legislature, or the loyalty of our colonists, could ever have effected."[193] The leading Britons on the project were knighted or made members of various orders of the Crown. "To an ocean state submarine cables are as valuable in time of war as are signalling arrangements and field telegraphs to an army on land…"[194]

It was not long before questions were raised with respect to international law…would a belligerent have a right to destroy a neutral's submarine cable that might be of use to an enemy? The United States Navy faced this dilemma when it went to war against Spain in 1898 and attempted to blockade the island of Cuba. The physical blockade was effective, but an information blockade was not possible until cables passing from Cuba to neutral nations were dealt with. The United States took the stance that within a neutral state's territorial seas (generally accepted as three miles) a cable was safe from tampering. But *outside the three mile limit* of neutrals, or within the territorial waters of a state at war it was within the rights of a belligerent nation to act against what might provide materiel assistance to an opponent. The U.S. Navy cut the Spanish cable at Cienfuegos. And offshore beyond the three mile limit at Santo Domingo, it cut another cable emanating from Cuba.[195] But even though the U.S. Navy had established a precedent in international waters in cutting a submarine cable, it was not an easy feat by any means. Fishing expeditions searching for enemy cables were often met with defensive gunfire; even finding a cable buried by sand or along a rocky bottom where grappling hooks had a difficult time at any regular search was problematic.[196] At its terminal ends were the weakest links of the submarine cable system, the most obvious points of vulnerability to effective attack. With this example, Great Britain eventually would go so far as to ensure an 'All-Red' line spanned the globe, avoiding Hawaii for a more difficult run to Fanning Island on the way to Australia from Vancouver to ensure all termini were in British control.[197] Nevertheless, in both World Wars of the twentieth century, undersea cables were cut to deny enemy usage;

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193 As quoted in Field, *The Story of the Atlantic Telegraph*, 201.
194 May, *Imperial Defence*, 163.
195 A.B. Feuer, *The Spanish-American War at Sea: Naval Action in the Atlantic* (Westport: Praeger Publishers, 1995), 75-82; May, *Imperial Defence*, 177-180.
196 Feuer, *The Spanish-American War at Sea: Naval Action in the Atlantic*, 77-82.
197 Bernard S. Finn, *Submarine Telegraphy: The Grand Victorian Technology* (Margate: Thanet Press, 1973), 41-43.

during the Cold War, a wiretap on a Soviet submarine cable was an intelligence coup until it was discovered.[198] It is readily apparent that submarine cables quickly became of tactical and strategic military importance; and from that initial splash of the submarine cable into the sea rippled some of the first signals that changes were afoot in the international laws of the sea.

From Maury's researches a veritable sea change occurred in the way that the oceans were viewed; the blindfolds were removed from the mariners that plied the seas of the world. But a number of other changes occurred, ripple effects from Maury's work that ranged from a new form of international cooperation, to a new way to war at sea as well as to a way to make the seas safer, and to an innovation that literally changed time-space relations for human society from that time forward. Maury's researches and insights were simple, really, inspired by straightforward questions about how to better do his job as navigator of a warship. By virtue of his position as a naval officer and by the Fates, Maury ended up in a place and at the time in the scheme of ocean navigation where his own experience allowed him to make lemonade from rather a lemon of an assignment. He leveraged a need of national level importance and was able to institute a program of research aboard naval vessels that bore fruit, and that led subsequently to an expanded program that reached the commercial marine and foreign navies and seafarers. At one point he had the opportunity to accept civilian sponsorship of some of his researches more germane to commerce and trade, but Maury chose to stay within the bound of his position as Superintendent of the Naval Observatory. Working through Congress he obtained the ships to conduct the ground (sea) testing of his theories and to then expand upon them in new and innovative ways.

That Maury's investigations happened to bear fruit just as one of the most visionary proposals of the century lay in question, and that the insights from these investigations proved definitive in moving that proposal forward, the Fates again may have been at work. The relationship of naval affairs and commercial affairs was even much more intertwined in the 19th century than today; to understand matters as security concerns that also have close commercial application requires some of the distinctions between naval and civil maritime interests also to blend. Maury represented a critical integration of these two national

[198] Ibid., 43; Sontag and Drew, *Blind Man's Bluff*, 158-183, 230.

interests and was truly a man for his times. As fickle as they are wont, however, the Fates also decreed a division of brothers in a great and terrible civil war, one that placed Maury on the losing side with the ignominy of defeat and exile until the waning years of his life. He was effectively removed from the labors that had brought to him fame, and to the world fundamental and monumental change.

And let the hands that ply the pen
Quit the light task, and learn to wield
The horseman's crooked brand, and rein
The charger on the battle field[199].

ΨΨΨ ΨΨΨ

[199] Willian Cullen Bryant quoted in Merle Curti, "The American Scholar in Three Wars," *Journal of the History of Ideas* 3, no. 3 (1942).

ΨΨΨ Chapter 4 Environmental Challenges to Post-Cold War Naval Operations ΨΨΨ

Full fathom five thy father lies;
Of his bones are coral made;
Those are pearls that were his eyes;
Nothing of him that doth fade
But doth suffer a sea-change
Into something rich and strange.[1]

Without quite the same Shakespearean alliterative eloquence – though certainly with a bit o' salt - mariners for ages have used the term *sea change* to describe marked alterations of sea and swell that serve as harbingers of ephemeral phenomena such as approaching weather, or that may indicate more enduring influences such as the presence of an ocean current or a shoaling sea bottom. Rather than just observational notes in a navigational log, there is a warning: *stay alert…something is afoot…remain vigilant*. Overused as a metaphor, the allusion of a sea change has lost some of its nuance and impact, but it is an appropriate simile when considering what has taken place at the intersection of ocean science and security in the opening years of the 21st century. Something *has* changed in how the oceans – and oceanography – function in the arena of security…and not only in the strict context of the interests of the United States as the focus of this study, although the U. S. plays a disproportionate role relative to the number of nations with security interests that intersect with the ocean environment. Because navies and naval air forces operate on, under and over a dynamic and geophysically variable ocean, environmental constraints on the conduct of naval operations persist as considerations irrespective of the dramatic strategic security transformation that has occurred since the end of the Cold War, but some of the feedback mechanisms that interconnect oceanic environmental and security parameters as discussed in the opening chapters of this study are subtly yet profoundly different.

Naval security concerns for the United States changed dramatically with the dissolution of the Soviet Union and a precipitous decline in concern over the nuclear missile submarine fleet that country had deployed throughout the Cold War. But the post-Cold War world of naval security interests is not devoid of traditional maritime considerations over maintaining open sea lines of communication, sea control and

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[1] William Shakespeare, "The Complete Works of William Shakespeare: The Tempest," 2003 (accessed August 20, 2006); available from http://www.shakepeare-literature.com/The_Tempest/2.html.

power projection. In that regard, the United States Navy enjoys an enormous asymmetric advantage over foreign navies, but still faces various challenges that are something of holdovers from Cold War days…including the difficulties associated with anti-submarine warfare against very quiet adversaries. Modern diesel submarines prove extremely difficult to detect while operating on batteries, and are steadily growing in the inventories of potential opponents for the United States Navy. A shift in the probable battlespace to the geophysically more variable littoral environment makes the post-Cold War world of antisubmarine warfare ironically even more challenging than the considerable dilemma the U.S. Navy faced in pursuing its Soviet adversary in the variable open ocean environment. This shift in venue combined with the stealth of the modern diesel submarine defines the most prominent environmental challenge for the U.S. Navy at least for the immediate future.

Also growing in emphasis in the Post-Cold War arena of environment and security – though nowhere nearly as succinctly as the diesel challenge described above - are linkages associated with environmental *change*, a category that until recently has received little attention but that may prove to have been more significant historically than previously understood if emerging clues from the geophysical record are being properly interpreted. Prominent in this genre – and intimately connected to the oceans via cycles of chemical, thermal and hydrologic transport - Global Climate Change (GCC) has implications for security that span the spectrum from tactical warfighting considerations to geo-strategic bearing on the integrity of economies and the very habitability of entire continental regions. Across this expansive range of scale, relevant environment-security linkages and feedback mechanisms vary broadly; and because this third investigative case (and the complementary fourth case which follows) considers the present-day state of affairs, some aspects remain inherently speculative. But the patterns that emerge upon reflection from the first two cases of this dissertation provide insights: challenges to post-Cold War era naval operations spawn requirements for ways to overcome environmental constraints, or to leverage the operating environment for military advantage; oceanographic scientific strategies subsequently are identified that address recognized environmental challenges to maritime operations, but that also concurrently trigger complex feedback mechanisms which further envelop or expand environment-security linkages…or potentially illuminate or engender altogether unique ones.

Across such a daunting seascape it is difficult to decide where to begin, but it is intuitive that the course of the future depends on recent history as much as it does on the present state of affairs. Emerging as the sole remaining superpower from decades of Cold War, the United States is uniquely positioned to determine largely the course of environment-security developments in the maritime realm.

Blue Moon at Waning Gibbous

Somewhere poleward of 66º 33’ 32” north latitude the Soviet Bear-D bomber descended to conduct a slow deliberate reconnaissance fly-by of the oceanographic survey ship underway on the frigid seas below. The Bear was the only propeller driven aircraft in service worldwide with a swept wing configuration; with this design, and four powerful Kuznetsov NK-12 turboprop engines mounting eight-bladed contra rotating propellers, it was also the fastest propeller driven airplane in the sky. In numerous variants the Tu-95 Bear was the backbone of Soviet bomber aviation; in the Delta configuration, it functioned as a long-range maritime patrol aircraft. In this role the Tu-95RTs traded weapons load for extended endurance and for space to mount powerful search radars and electronic intercept sensors; nevertheless the lumbering Bear-D was capable of making it an extremely bad day for a surface vessel: the I-band frequency search radar housed within the large bulbous radome midway on the underbelly of the fuselage provided cueing information and mid-course guidance for surface-, air-, and submarine-launched anti-ship cruise missiles. Dubbed with the visually descriptive NATO classification moniker “Big Bulge,” the conspicuous distended housing for the sensor together with a smaller “chin” radome beneath the cockpit presented the primary aircraft profile identifiers distinguishing this Tupolev 95 from other bomber variants.[2] With no bomb bay doors to open, or weapons hung from non-existent wing pylons, the hulking turboprop revealed nothing of its intentions as it eased into level flight just above masthead height of the ocean surveyor. If harm was imminent, it would appear from elsewhere and streak in supersonically just above wave top level to evade radar detection and tracking, and then abruptly jolt into a deceptive terminal stage of flight to avoid a hail

[2] Polmar, *Guide to the Soviet Navy*, 257-261; "Tu-95 BEAR (TUPOLEV)," August 08, 2000 (accessed April 27, 2005); available from http://www.fas.org/nuke/guide/russia/bomber/tu-95.htm; "Tupolev Tu-95 & Tu-142," (accessed April 27, 2005); available from http://www.aeronautics.ru/archive/vvs/tu95-01.htm.

of depleted uranium armor-piercing projectiles fired at thousands of rounds per minute from close-in weapons defense systems…that this survey vessel lacked altogether.

The vulnerable ship that was the focus of the Bear's attention was a converted merchant - the former *S.S. Canada Mail* – over 500 feet in length while displacing greater than 15,000 tons and whose superstructure remained dominated by five distinctive vestigial cargo A-frames despite its functional conversion into a survey platform with the addition of a deep ocean sonar sounding system on her hull athwart the keel. Although clearly a non-combatant by an even cursory visual inspection, the vessel was painted haze gray and distinguished by yellow and blue stripes that circled the smokestack – an identification scheme that indicated she was owned and operated by the U.S. Navy; hull markings on the bow identified the former mail carrier as an auxiliary: geophysical survey, number 38. Topside on the flying bridge above the pilot house gathered some of the embarked American naval officers, sailors, civilian scientists and crewmembers. They smiled and waved at the telephoto lenses that were surely fixed upon them from the Bear-D's observation canopies, and gestured to advise the airborne Soviet observers that the air temperature at the sea surface of the Arctic Ocean had dipped into the single digits. Over preceding clear Arctic nights those onboard the survey vessel had been awed by the evanescent splashes of color and the spectrally shifting fluorescing curtains of light when the Aurora Borealis shimmered against a flawlessly black sky filled with pinpoint stars and the faint image of a new moon. In stark contrast during daylight hours it was the efficient and impersonal visits by the long and sleek swept-wing bomber with the blood red star on the tail that left the Americans transfixed. The silver silhouette against the gray of the Arctic Spring sky was a sobering reminder that despite the smiles and waves, the affable low-temperature hand signals and the occasional near-the-horizon lunar event - that gave altogether new meaning to the expression 'blue moon' - it was serious business in which they were engaged.[3]

Some months after they likely had been the subjects of annotated briefing slides in some far away intelligence summary in Severomorsk or Vladivostok – hopefully ones without *too* refined pixel resolution - *USNS H.H. Hess* (T-AGS-38) and its embarked *Oceanographic Unit THREE* returned to port in Norfolk,

[3] The author served as Executive Officer of the embarked oceanographic unit during this account of late-term Cold War operations.

Virginia where the last entries in their log books were recorded. *Hess* was earmarked for transfer to a civilian maritime training academy, although a subsequent boiler accident made her unserviceable for this purpose and she was stricken from the Naval Register of Ships in February 1992 and sent for lay up with the National Defense Reserve Fleet.[4] Even more telling for the times than the act of taking a military oceanographic survey ship out of commission - for *Hess* was an old ship nearing the end of her serviceable life, and more modern deep-ocean survey ships had been built and were then working out (rather substantial) engineering kinks as they were becoming operational - *OCUNIT THREE* became the first of the deployable deep ocean survey units of the U.S. Naval Oceanographic Office to decommission. The other two units followed quickly as the Ocean Survey Program that sent them to sea declined steadily in importance in synch with Cold War tensions. The two almost-new survey vessels built to accommodate *OCUNIT*s *ONE* and *TWO* when they embarked, *USNS Maury* (T-AGS-39) and *USNS Tanner* (T-AGS-40) saw little active service before they too were struck from the Naval Register by 1994.[5]

In Spring 1991 the threats which had provided much of the impetus for the enormous and expensive task of conducting high seas oceanographic surveys – the vast attack and ballistic missile submarine fleets of the former Soviet Union – were withdrawing from the patrol areas they had occupied for decades as the Soviet front line naval forces of Mutually Assured Destruction. Additionally, the necessity for deep ocean survey that supported the United States' reciprocal naval leg of the strategic deterrence triad similarly diminished as security requirements were reassessed and reprioritized in response to the transforming Soviet stance. Oceanographic programs and underwater acoustic detection systems that provided the U.S. Navy with critical information to address the challenges of undersea warfare throughout the Cold War - that leveraged the scientific understanding of the physics, biology, geology and chemistry of the oceans to provide clarity in an otherwise opaque search environment - were consequent casualties of budgeting decisions which sought to rectify desired peace dividends against validated security concerns as they were

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[4] Gary P. Priolo, "T-AGS-38 H.H. Hess," *NavSource Naval History*, August 28, 2004 (accessed April 28, 2005); available from http://www.navsource.org/archives/09/1038.htm.
[5] John Pike, "T-AGS 39 Maury Oceanographic Survey Ship Golden Bear Training Ship," August 18, 2004 (accessed April 29, 2005); available from http://www.globalsecurity.org/military/systems/ship/tags-39.htm.

perceived in those tentative times.[6] With the general withdrawal of the Soviet Navy from the arena, naval threats in the aftermath of the Cold War were uncertain; but what was evident was that few probable adversaries of the United States Navy demonstrated the capability to operate beyond territorial seas or at any significant distance from home waters for extended duration. For the first time in decades the U.S. Navy anticipated that maritime challenges were more likely to be encountered closer to coastlines in the littoral regions of the world rather than in the 'blue water' of the open seas. There in the relative shallows above the continental shelves, in an area that was geophysically even more dynamic than the open ocean and that was subject to additional environmental parameters affecting various aspects of undersea warfare, would be found the 21st century nexus between ocean science and security.[7]

The work of U.S. Navy Lieutenant Matthew Maury in the 1800s first demonstrated the importance of having naval officers that understood the operations of the U.S. Navy and could then take the additional step of understanding the geophysical constraints that the maritime operating environment placed upon naval forces in order to optimize their performance. This legacy exists today in the United States Navy through a core of specialty officers and enlisted men and women that are dedicated to providing frontline warfighters with information about the effects of the marine environment on strategic and operational levels of warfare; advising decision makers about the impact of oceanographic and meteorological processes on naval platforms, weapons, and sensors at the tactical level; and maintaining the safety and efficiency of fleet and shore-based naval operations.[8] Naval oceanographers recognize – as did Maury – the fluid interface between atmosphere and ocean and for this reason develop proficiency in both meteorological and oceanographic processes to provide seamless expertise related to this complicated marine battlespace. In addition naval oceanographers are trained in mapping and charting disciplines and are also the historical caretakers of precise time for military operations, a field that has progressed from the times that Maury directed the operations of the Naval Observatory in producing astronomical tables to aid

[6] These programs were not done away with entirely, but emphasis clearly shifted from the open ocean concentration of the Cold War to the littorals in the span of only a few years in the early 1990s.
[7] Michael J. Carron, Steve Haeger, and Paul LaViolette, "The Challenge of the Coastal Shallows," *U.S. Naval Institute Proceedings* (1994); *Quadrennial Defense Review Report* (Washington, D.C.: Department of Defense, 2006).
[8] Oceanographer of the Navy (CNO N096), *Operational Oceanography and the Move into the 21st Century: A Presentation to the CNO Executive Board* (Washington DC, 1995).

navigators in the celestial navigation of their vessels to the present day maintenance of precision atomic clocks that form the basis of time-derived geopositioning by means of a constellation of low-earth orbiting satellites.

In Maury's day naval oceanography was collateral to primary duties of the line; early oceanographic expeditions were conducted by line officers not specially trained in the physics of fluid dynamics other than through the years they had been schooled by the strictest and most unforgiving teacher imaginable – the sea. As the duties of the Naval Observatory became more formally a part of naval operations throughout the latter half of the 1800s, a core of naval oceanographic expertise developed but it was not until much later after the experiences of World War II that scientifically trained naval officers became dedicated naval oceanographers. Meteorological expertise became of signal importance to naval operations - aside from Maury's researches into the safe and efficient navigation of vessels under sail – with the advent of naval aviation in World War I. Aerographers were trained in the still evolving science of meteorology from this point forward and eventually formed a rating of the enlisted service that persists to the present day as the enlisted expertise of naval oceanography. Collectively the role played by the community of oceanography officers and Aerographer's Mates is a litmus of sorts that reflects the dynamic emphasis – or lack thereof - that is observed by naval leadership regarding environmental constraints upon naval operations; the shifting priority and focus that is placed upon various facets of their expertise reveals much about the current threat perception from the perspective of the United States Navy.

When the author joined the U.S. Naval Oceanography community in 1990, the naval forces of the Soviet Union remained the primary threat against which the U.S. Navy trained and expected to fight one day – however desperately it was hoped that outcome might never come to pass. Early assignment to a deep ocean survey unit and subsequent assignments to satellite remote sensing activities and aerial survey operations were all focused upon this singular naval threat: Soviet undersea warfare. With the dissolution of the Soviet Union however the open ocean anti-submarine warfare emphasis of the U.S. naval oceanography community waned almost immediately. The following years saw the pendulum swing from focusing attention on deep water acoustics as an element of antisubmarine warfare to placing greater

emphasis on the meteorological facet of naval oceanographic expertise in support of strike warfare; aviation forecasting and the prediction of atmospheric environmental effects on sensors and weapons selection and performance grew in prominence. Littoral environmental constraints on special operations (SPECOPS) and mine warfare (MIW) also came into greater focus as expeditionary warfare became a centerpiece of American naval strategy in the 1990s. In the background ASW did not disappear altogether, but the enormity of the change in emphasis from open-ocean to coastal operating environments as viewed from a geophysical perspective made shallow water ASW such a challenge that until such time that threat specifically reared its periscope in earnest this facet of naval oceanography did not remain center stage.

The diminishing emphasis on antisubmarine warfare in the aftermath of the Gulf War in 1990-1991 led some wags to suggest that the acronym be re-jiggered to stand for “anti-scud warfare” or “anti-sand warfare.”[9] The hard lessons of earlier anti-submarine warfare challenges were not lost on naval planners, but in the days of highly scrutinized defense budgets the here and now dominates the process much more than the potential for future threats. It would take a decade of post-Cold War operations before the submarine threat returned to any prominence as far as naval strategy was concerned, and then primarily as a future concern since more immediate maritime threats and security matters for the U.S. Navy continued to be of the type addressed via strike and expeditionary warfare. Those countries that sought submarines on the open market after the end of the Cold War made them more available commodities faced a learning curve measured in years for achieving true operational capability once they procured the boats, and until such point that they developed the expertise to deploy their submarines for extended periods at sea where they might achieve and maintain stealth to the degree that they pose a threat to U.S. naval forces there remained some sense of a respite from dedicating assets or resources to address the pending undersea challenge.

For the reasons outlined above, this aspect of naval warfare therefore languished somewhat lower on the totem pole of requirements – although in recent months as of this writing has gained significant attention for future naval planning, and in that regard a particular renewed emphasis of the naval oceanography

[9] Jim Bussert, "The Destruction of U.S. Anti-Submarine Warfare," *Defense Electronics* April (1993): 51.

community. However, even at the point that adversaries gain proficiency in submarine warfare, there will still be a matter of numbers that will constrain the relative threat perception; if an adversary has only a few submarines, a peremptory inport strike or a relatively short and intensive hunter-killer operation might remove this threat altogether from the equation. Not until the submarine threat proliferates in sufficient numbers and operational capabilities among identified adversaries will this facet of undersea warfare rise in prominence to become once more a primary focus of the United States Navy in a manner commensurate with its Cold War emphasis. The argument is far from moot…substantive submarine threats would pose grave and immediate danger to naval forces; in fact the emergent contemporary debate over whether some potential adversaries of the United States have achieved capabilities that justify elevating the priority of this threat – especially in the Pacific - makes it difficult for the author to decide whether this uncertain forecast should be written instead as analysis.

The Browning of the Blue Water Battlespace

Something there is that doesn't love an ASWEPS forecast, that complicates its constituent geophysics, and makes insufficient data that once sufficed, leaving gaps through which undetected two submarines could pass abreast.[10] With a little license – or maybe quite a lot - this might have been Robert Frost's observation to the progressively more difficult antisubmarine warfare (ASW) challenge that developed in the latter years of the Cold War and that with some nuances is representative of the undersea warfare problem of the present day. The Soviet submarine threat was the greatest naval challenge ever faced by the United States, and enormous energy was expended on antisubmarine warfare; much of that effort was focused upon resolving the geophysical effects of the operating environment on ASW sensors and weapons. The Antisubmarine Warfare Environmental Prediction System and the alphabet-soup of acronymic progeny that succeeded it were environmentally informed tactical decision aids (TDAs) that contributed greatly to the effective maintenance of the sonic barricade the U.S. emplaced in strategic locations of the world's oceans to defend against the undersea threat. The Soviet Union's submarines were forced to negotiate this acoustic gauntlet to reach operating zones within reach of targets in the United

[10] Something there is that doesn't love a wall, That sends the frozen-ground-swell under it, And spills the upper boulders in the sun, and makes gaps even two can pass abreast.

States until late in that conflict when the range of submarine launched ballistic missiles enabled the Soviet strategic submarine force to deploy in waters closer to their home ports.

Substantial success at long-range detection and tracking of Soviet submarines was achieved early with this top-secret acoustic defense – later revealed to the world as the Integrated Undersea Surveillance System (IUSS) of which undersea hydrophone arrays that made up the Sound Surveillance System (SOSUS) served as the primary fixed elements. These successes proved ephemeral, however, because improved quieting techniques and technologies made Soviet boats progressively more difficult to discern as the Cold War wore on, even as knowledge of the ocean operating environment and the sophistication and effectiveness of environmentally-informed TDAs concurrently improved. To be sure, the fact that Soviet missile boats were no longer required to transit certain strategic chokepoints where SOSUS arrays might pick up their "scent" while on their way to patrol stations was an important strategic and tactical consideration that diminished the utility of the IUSS system; nevertheless Soviet attack submarines still traversed this acoustic cordon to search out their prey: American Trident ballistic missile submarines. The extended range of the Trident missile allowed American "boomers" to patrol within range of Soviet targets while well beyond Soviet waters, and outside of the bathymetrically determined ingress/egress chokepoint passages between northern Soviet ports and the open Atlantic and Pacific Oceans that simplified the "big-ocean" detection problem by narrowing initial search areas.

If Soviet sharks of steel – a nickname for all submarines, but the NATO designation for the latest and greatest titanium-hulled deep diving Soviet attack submarine was actually *Akula…Shark* – wanted to make contact with prey, they were forced to do so in their adversary's patrol grounds. The fact that Soviet boats had to pass through the American acoustic listening range did not guarantee detection, however. Antisubmarine warfare in general was an inherently difficult task – made even more so against a formidable adversary that recognized how to complicate the problem within a variable ocean environment whose physical parameters affected sensor performance spatially and temporally and consequently constrained targeting solutions and weapons accuracy. The shrinking margin of advantage afforded by superior understanding of the ocean battlespace made oceanographic research ever more critical to the

United States in the closing years of the Cold War. Yet paradoxically when that conflict waned and passed into history taking with it the United States Navy's primary adversary, environmental aspects of anti-submarine warfare became even *more* of a convoluted challenge despite the years spent resolving environmental effects on sensors, weapons and tactics.

The foremost Cold War naval challenge that United States Navy forces trained to fight – attack and ballistic missile nuclear submarines - quickly faded with the end of the decades-long confrontation between the United States and the Soviet Union, but this does not mean that undersea challenges disappeared altogether for the U.S Navy... A complicated international security situation emerged from the aftermath of the Cold War. Deployed around the world in an ever-expanding role to respond to various regional crises, the U.S. Navy sought to adapt its Cold War structure to meet new threats anticipated in the littoral areas of the coastal margins – threats that bore little resemblance to the powerful Soviet Navy in strategy or force structure. If a naval example of military asymmetry were required, it could be found easily by comparing the U.S. Navy to virtually any foreign fleet in the post-Cold War period. Many maritime nations possess navies, but none of them deploy anything akin to the fleet the Soviet Union sent to sea that was capable of projecting power far from its home territory and designed to fight in the "blue water" of the open ocean. While Soviet naval structure never strictly mirrored the U.S. fleet – in carrier aviation for example or in underway replenishment capability – it nevertheless was designed to project Soviet power and counter American naval presence on the high seas.[11]

By the early 1990s, however, Soviet naval assets were dispersed among the former republics and the Hammer and Sickle fleet no longer dogged the U.S. Navy at every turn. With a few exceptions primarily found among the maritime nations that represented America's Cold War allies – and whose force structure was designed to interoperate with the U.S. fleet - most modern navies might be considered coastal defense navies rather than ones intended to project national power far from home shores. This disparity of maritime force structure does not mean that there are no responses to American naval strength available to a potential adversary…and when presented with an asymmetric challenge, some responses are better than

[11] David Fairhall, *Russian Sea Power* (Boston: Gambit Incorporated, 1971), 257-261.

others. In naval annals one historically effective response to a stronger adversary has been through methods of undersea warfare. A Navy "on the cheap" can be fashioned using mines and small patrol boats armed with anti-ship missiles for coastal defense and can be made all the more effective through the employment of submarines for their stealth in a sea control and interdiction role as a constant threat to adversary naval forces. A deployable offensive "blue water" nuclear submarine force such as the one sent to sea by the Soviet Union is not something a new potential adversary of the United States might quickly constitute to bring the fight beyond the littorals, but acquiring 'off-the-shelf' diesel submarine technology i*s* an option which some nations that might be considered less than friendly to the U.S. are able to pursue to fight effectively in or near home waters.

Restricted underwater endurance makes diesel submarines of limited value for open ocean operations – the primary factor which constrains their ability to project power such as had been accomplished by the Soviet nuclear fleet during the Cold War - but diesel subs have significant advantages that can not be overlooked. They are reasonably inexpensive and available on the open arms market, and can accomplish a variety of missions ranging from interdiction and sea control to some limited strike missions as well as special operations and intelligence gathering. Since they are diesel powered they are effectively turnkey weapons systems as compared to the extensive engineering training and maintenance skill required to operate nuclear submarines. Diesel submarines also enjoy a capability that nuclear submarines lack, something that suggests that some of the lessons learned from the early days of holddowns need to be dusted off: diesels have the ability to bottom and remain quiet. Nuclear submarines must continue to pump seawater through cooling systems to carry away the heat from the nuclear reactor and cannot foul inject ports by sediment. What is more, with the introduction of air-independent propulsion (AIP) systems, the newest diesel submarines can achieve underwater endurance in the range of weeks rather than days – perhaps even exhausting the surface pursuit vessels' on-station endurance without resupply.

While procuring a fleet of diesel submarines does not imply an instantly "capable" submarine threat, it does mean that the potential exists and that the United States would be forced to dedicate resources to address the undersea challenge, especially to protect high-value assets such as aircraft carriers – the loss of

which would be of a propaganda value arguably equivalent to the actual loss of combat power because of what these acres of sovereign territory represent to the many nations that lack this potent aspect of power projection. In addition to these already favorable considerations for electing an undersea warfare strategy, an enormous advantage that the diesel submarine brings to the fight is the difficulty it poses to antisubmarine warfare forces as a result of its stealth while running on battery, something it achieves to even greater effect amidst the clutter of a noisy coastal environment – the synergistic nuance that makes these platforms as tough an ASW problem as the quietest Soviet boats that went to sea. When the end of the Cold War dispersed the Soviet open ocean threat, it was precisely towards this coastal environment that security analysts looked to discern 21st century naval threats and challenges for the U.S. Navy. Consequently American naval focus shifted from the (then) familiar open ocean operating environment to the littoral regions of the world which - in addition to adding more variables such as territorial concerns and highly trafficked shipping lanes, fishing grounds and other economically intensive activities which can impede or at least cause difficulties for naval operations - are also geophysically more complex, a factor which greatly complicates environmental aspects of naval warfare.

It is rather simple to state that the move from the open ocean to the coastal shallows makes acoustic detection more difficult, but this statement may not prove intuitively obvious to the most casual observer. Earlier it was discussed that sound propagation was affected by the physical parameters of the water column – primarily temperature, pressure and salinity. Following the idea that temperature and pressure vary with depth, the reader learned in an earlier chapter that barriers to and conduits for sound travel are dynamically formed in the water column.[12] It is then rather obvious that in comparing different areas where parameters such as water temperature differ, the propagation of sound will demonstrate differences; and equally apparent is the observation that in shallow water one may not have the available depth for temperature effects to be overcome by pressure effects in determining how sound propagates in the water column. These are parametric differences that the casual observer would be readily qualified to point out, and logically would expect to encounter variably in nearshore environments. But our observer might need to swim in the vicinity of a river outlet, especially during times of copious precipitation runoff to taste

[12] Robert Frosch, "Underwater Sound: Deep-Ocean Propagation," *Science* 146, no. 3646 (1964).

additionally the change in salinity that becomes apparent over relatively short distances, variances that are not so prevalent in open ocean environments and that now have a higher degree of influence upon the propagation of sound. And while the swimmer might notice the roar of the surf and surmise that those sounds might propagate offshore to the degree that interference with acoustic searches are possible, it might be overlooked that even the mixing processes of fresh and salt water have flow noises and molecular motions that affect how sound moves through the water column.

Many more factors also conspire to complicate the littoral environment. A range of bottom types of varying acoustic transparency and rapidly changing bathymetry impact sound transmission and consequently affect acoustic detection ranges. Land-based noises that propagate through bedrock and out into the ocean environment add to the sonic clutter. Greater shipping densities and nearshore operations such as dredging, drilling, and construction as well as flow noises through pipelines and that are caused by tidal surges and turbidity currents all add to the sound environment in the shallows. Biological activity is also much more a factor in shallower water regions. Fisheries exist primarily in the areas above coastal shelves and not in the open oceans for one primary reason: that's where the fish are! The ecological food web is in full cycle in nearshore regions, and the chorus of sound added by the clicks, clacks and whistles of marine life are joined with the resonance of piscine air bladders and scattering effects of planktonic carapaces to acoustic energy. The impact of biologics on ocean acoustics can be significant: the sound scattering effects of microorganisms eventually accounted for an early mystery that puzzled ocean acousticians. False bottoms appeared to early depth sounders when scattering layers of variable depth were observed; it was not until scientists determined that sea creatures migrated diurnally through the water column in sufficient numbers to cause these returns that these mysterious echoes were explained.[13] In a similar fashion, distracting noise that interfered with early sonar sets sounded like bacon frying to frustrated operators trying to locate submarine contacts; the interference was eventually traced to the activity of snapping shrimp. Indeed the littoral environment is anything but a *Silent World*.[14]

[13] "Sound-Scattering Layer in the Ocean," *New York Times*, October 11, 1953.
[14] An excellent account of the increasing complexities of ocean parameters with the move from the open ocean to the littoral can be found in Carron, Haeger, and LaViolette, "The Challenge of the Coastal Shallows."

For close to forty years while the Cold War thrummed along without apparent relent, underwater acoustic detection systems comprised the central nervous system of undersea warfare strategy for the United States. The Integrated Undersea Surveillance System provided cueing information to U.S. Navy and allied aerial, surface, and submarine assets which used this notification of a target's presence and general location to seek out, localize and maintain contact with Soviet submarines throughout their deployments. ASWEPS and other environmentally informed acoustic sensor performance prediction systems provided these naval ASW forces with information about how the physical ocean environment influenced sound propagation patterns for hull mounted, towed array and deployable naval sonars. Based upon oceanographic climatic history and (when available) near-real-time sensor data, ASWEPS also predicted the presence and structure of the deep sound channel that facilitated the long range transmission of low frequency sound upon which IUSS was focused in order to optimize the operation of the suite of ASW sensors and weapons systems.

In the deep water basins of the open ocean where opposing submarine forces of the Cold War patrolled, relevant geophysical parameters varied both temporally and spatially, and over such a wide area were difficult to synoptically sample in order to generate real-time acoustic analyses and forecasts for operational use. In regions where these parameters were reasonably homogenous, first-best estimates were accurate enough to be of some use and the detection problem became one of signal to noise ratio independent of range other than those factors of spreading, attenuation and absorption of sound that plagued any detection scenario; but in regions where geophysical parameters varied significantly enough, acoustic propagation paths became of consequence and the ASW problem was known as range-limited or range-dependent. Natural variance of sound-influencing parameters such as the structure and locations of ocean thermal fronts and eddies often transpire along a seasonally prescribed general range and pattern, but like the weather are prone to short-term fluctuations that might be of tactical significance in a "shooting match." Consequently the U.S. Navy committed to an extensive program of oceanographic survey to resolve three-dimensional temporal and spatial means for physical properties – primarily temperature and salinity - that were used as system baselines to support the first-best guess estimation for optimal sensor

deployment and for signal processing, and as a point to deviate from when more timely environmental information was made available.

The effort to collect environmental information in the oceans to characterize the effects on sound propagation was enormous. Data collected by surface ships; from thermal and acoustic sensors dropped by aircraft; by earth-orbiting satellites with visual, infrared and radar sensors; and that was telemetered via satellite links from sensor arrays deployed beneath drifting buoys was used to determine climatic means and initialize predictive numerical ocean models. A great deal of additional research was undertaken beyond the simple collection of physical data to investigate the behavior of underwater sound at the sea surface boundary under various conditions of weather, winds and seas; the same manner of inquiry was conducted at the sea-bottom interface where bathymetry, bottom type and the structure of the subsurface strata played important roles in acoustic propagation. Gradually and through much trial and error the propagation of underwater sound became better understood; with timely and accurate information about the state of the environment, open ocean antisubmarine warfare was a more tractable problem.

The collection of this enormous basin-wide body of geophysical information and the conduct of area-dependent research on the propagation of sound at the sea surface and sea bottom boundaries required hundreds of ship-years of intensive surveys to gather and investigate parametric data of interest. Compiling physical atlases and climatology databases in this fashion was painstaking and laborious, but succeeded in providing a first-best guess estimate at the performance of weapons and sensors in order to plot tactics and exploit cueing information without the benefit of more timely environmental information that might not be available for any number of operational reasons. Against an enemy steadily making progress at masking his acoustic signature amidst the ambient noise of the operating environment – and who all the while was pursuing similar environmental research to the same ends – oceanographically leveraged advantages were hard-won. Tactical warfighting requirements inspired development of ever more flexible fixed and deployable sensors and environmentally informed decision aids. To facilitate the near real-time refinement of the thermal structure that accounted for most of the refractive effects of underwater sound propagation in the upper ocean, sensors were devised that could transmit information via tethered cable or by radio

frequency directly to surface, subsurface and aerial warfighting platforms (as opposed to delivering the data to dedicated oceanographic collection platforms that did not go to sea armed for a fight) during naval maneuvers to provide the precision that climatology lacked and that acoustic search sensors and weapons systems required for optimum performance. As computing power improved, tactical decision aids were developed that could be run at sea or in the air by onscene units rather than on mainframes at shore processing sites that then had to be messaged to the fleet for exploitation.

While substantial success was achieved in applying oceanography to antisubmarine warfare, it represented the cumulative efforts of almost fifty years of study of the behavior of sound in seawater to resolve the parametric effects of physical variables in order to isolate their individual and collective contributions to underwater acoustics and to then develop tools to sample the most critical of them in timely enough fashion to make the information of tactical use. As it was, this Cold War effort to resolve the effects of the dominant physical variables in the open ocean was a massive undertaking; but the number and variability of parameters of these “blue water” regions pale in comparison to the range of parameters that influence the “shallow water” acoustic conditions of the coastal littorals. And since the end of the Cold War, the reasonably well understood open ocean Soviet submarine threat has been displaced by a more nebulous panoply of undersea threats deployed by a greater spectrum of potential opponents that are expected to operate in the coastal shallows.

Irrespective of submarine design, shifts in operational tactics and changes of venue with respect to the areas of the oceans to which they are deployed, the primary asset that a submarine provides to a naval force remains its stealth and the primary challenge for opposing antisubmarine warfare forces remains detection. It is essentially that simple. The submarine persists as a threat as long as its whereabouts remains unknown and it’s potential to inflict damage extant. From the alternative view, once a submarine is detected, tracked and localized it’s shelf life has effectively been reached provided the basic hunter’s premise is met that one hunts what one can kill and the searcher possesses effective antisubmarine weapons. Simple in theory, this process is deceptively difficult in practice. Detection must take place before adversary submarines reach

weapons-release ranges (the "enemy in range" maxim still holds), so broad area search with sufficient detection range is the essential requirement of antisubmarine warfare.

The "big ocean" search problem is limited somewhat by constrained coastal operating parameters – land remains a hazard to navigation, so submarines must remain seaward of certain bathymetric contours – but there is still a great deal of waterspace available for stealthy submarines to operate. Localization upon initial detection also remains a complicated issue: shallow wrecks and pipelines present magnetic anomalies that airborne magnetometers must distinguish from a target's magnetic signature. In regions of sufficient magnetic clutter it could be exceedingly difficult to localize a bottomed submarine, but again that is a matter of *localization* and not initial detection which until some other method arises remains primarily a matter of sonar. With sound still the primary method of underwater detection, the dual problem of quieter submarines and noisier operating environments conspire to create effective breaches in the underwater sound barricade that the United States enjoyed via the detection capability of the IUSS system. But unlike the breaches Frost and his neighbor closed in *Mending Wall*, the gaps in the underwater sound barricade are environmentally derived parameters rather than physical elements like the fallen stones of the allegory. What is more, it quickly becomes apparent that the same "stones" of the earlier IUSS barricade no longer suffice.

Passive detection via the deep sound channel becomes problematic with a quieter generation of submarines emanating less noise, and proves equally challenging with the geographic and acoustic limitations of low frequency sound propagation near coastal shallows. With detection ranges of higher frequency hull-mounted search sonars also significantly impacted by variable coastal environments and acoustic clutter, the ASW challenge is significant. Rather than just attempting to 'burn through' the acoustic variability and clutter of these 'brown water' inshore regions using higher source power – a tactic with its own limitations because of reverberation effects - alternate underwater surveillance techniques have been investigated and naval oceanographers and scientists still have much to evaluate regarding their effectiveness as implements for undersea warfare. Possibilities exist to exploit the bioluminescent excitation of plankton or to identify submarine wakes even while vessels remain submerged; and there is

potential to utilize technologies such as blue-green laser detection in coastal environments. But these are short range detection strategies at best, and detection range is the key parameter for success in ASW. With the similarity of the littoral detection problem to one encountered at the end of the Cold War when Soviet submarines became significantly quieter, a strategy under development near the end of that conflict has again become of interest to naval oceanographers and ASW forces and the focus of renewed investigations. And as might be expected from the already reviewed track record of applied ocean science and security interactions in the first two case studies, the testing, evaluation and fielding of new systems and methodologies can create direct and indirect ramifications of their use that are entirely unexpected.

The Sounds of Silence

While listening to a symphony orchestra an audience enjoys a blending of sounds of many frequencies and intensities produced by a range of musical instruments. The conductor directs sections of his orchestra to greater and lesser emphasis throughout the musical composition and the listener distinguishes and appreciates the winds, strings and percussion as they stand out among the harmonies. This is not unlike the scientific discipline of underwater acoustics. Mechanical, biologic and geophysical sounds of various frequencies and intensities merge to make the underwater environment anything but a *Silent World*. The undersea realm that Jacques Cousteau described in his first book initially might have appeared silent because of the relatively limited capacity of the human ear to discern or discriminate the cacophony of sounds at frequencies and intensity levels above and below human auditory capacity. But sensitive hydrophones and signal processing can distinguish a broad range of underwater sound, and the research and development associated with engineering such systems dominated the world of Cold War oceanography. Determining and cataloguing natural sources of sound to discriminate manmade noises that are inadvertently introduced into the water column, and characterizing the manner in which sound propagates in the environment were of primary importance to the antisubmarine warfare effort that focused upon the Soviet threat throughout that conflict.

Like the listener in the symphony analogy, a sonar operator can discern specific noises if the frequencies and patterns that they make aurally or in the video processing of sound signals are known; a trained technician can pick these signals from what appears to the novice as clutter because he is familiar with the signals and knows where to look. And just as the awkward squawk of a badly played note, broken string, or split reed might draw the attention of the conductor or audience to the unfortunate musician's vicinity onstage, similar tonals within the symphony of underwater sound draw attention. In this instance these tonals are specific to particular types of machinery or operating characteristics and a dropped wrench on a metal deckplate or an improperly maintained piece of equipment can make the difference between stealth and a veritable bull in a china shop. The obsessive focus of submariners on quiet running is not (merely) a neurosis, but a mission essential characteristic and even a life or death matter under the right set of circumstances.

As would be expected, quieter submarine designs achieve stealth more effectively among the spectrum of underwater sounds that clutter the search picture. Lowering the submarine's acoustic signature improves stealth, and similarly operating in an area of greater sonic clutter serves to mask those sounds that are emitted by a submarine despite best efforts to damp them. The improvements achieved by Soviet naval architects in submarine quieting at the end of the Cold War went a long ways in achieving the first objective in complicating the efforts of U.S. ASW forces; the shift in the post-Cold War operations to shallow water environments effectively – even if coincidentally - leverages the second. Because Cold War nuclear submarines operated in the less forgiving acoustic environment of the open ocean throughout that conflict, highly specialized technologies were developed to make them increasingly silent. When these quieting methods and technologies are applied to already stealthy diesel submarines and operations are then shifted to the acoustically more favorable (for submarine stealth) coastal shallows, antisubmarine warfare becomes that much more difficult. Instead of a bad reed or misplayed note to draw the awareness of the audience, one now needs the tuba player to fall into the wind section.

When it became apparent late in the Cold War that Soviet submarines were significantly quieter than they had been only a short time earlier, it was immediately evident that the acoustic advantage that the

United States had enjoyed was marginalized. Espionage had apparently tipped off the Soviets with regards to the degree that their submarines were compromised by their comparatively noisy design;[15] in the 1960s and early 1970s, numerical strength had been sought by the U.S.S.R. at the expense of the extra design and attention to construction techniques that would have been required to make the boats quieter – a strategy the Soviets reevaluated and addressed once the cat was out of the bag.[16] Acoustic decoupling of machinery from submarine hulls via shock mounts and "floating" machinery rafts; anechoic coatings to reduce acoustic target strength; and improved machining of propellers to reduce cavitation effects (via the illegal procurement of multi-axis milling machines from the Japanese firm Toshiba) almost immediately made Soviet boats altogether different targets for underwater detection and tracking.[17]

Between 1977 and 1988 it was estimated that the Soviet Union had achieved quieting of radiated noise levels from its submarines by some 30 dB – a factor of 1000 – which equated to decreased detection ranges from thirty-fold to one thousand-fold depending upon the specific oceanographic operating environment under consideration![18] All the kvetching over espionage leaks and sales of equipment on restricted lists could not recover the lost acoustic advantage, and naval oceanographers and engineers returned in earnest to the drawing board to find the next greatest tool for antisubmarine warfare. The path, however, was not a blind one; the physics of underwater acoustics remained consistent, and the way was evident even if the research and design effort remained to be worked out. The extended passive detection ranges that had been realized by the successful IUSS suite were achieved at lower frequencies that propagated via sound channels; the effective harnessing of such a technique demonstrated a certain element of subtlety and scientific finesse to a difficult naval challenge, one that might yet be further exploited.

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[15] Bill Keller, "Spy Case is Called Threat to Finding Soviet Submarines," *New York Times*, June 6, 1985; William A. Kuperman and James F. Lynch, "Shallow-Water Acoustics," *Physics Today* 57, no. 10 (2004).
[16] Drew Middleton, "Antisub Warfare: Soviet Trying to Catch Up," *New York Times*, November 20, 1893.
[17] Alun Anderson and David Swinbanks, "Japanese Mill Given Credit for Stealthy Soviet Subs," *Nature* 327, no. 7 (1987): 7; Alun Anderson and David Swinbanks, "Storm Brewing Over Toshiba's Illegal Exports," *Nature* 328, no. 9 (1987): 98; Office of Naval Intelligence, *Worldwide Submarine Proliferation in the Coming Decade* (Washington DC, 1994); Walter Sullivan, "Can Submarines Stay Hidden?," *New York Times*, December 11, 1984; David Swinbanks and Alun Anderson, "Has Japanese Technology Made Possible Quiet Soviet Subs?," *Nature* 328, no. 23 (1987): 283.
[18] Gordon D. Tyler, Jr., "The Emergence of Low-Frequency Active Acoustics as a Critical Antisubmarine Warfare Technology," *Johns Hopkins APL Technical Digest* 13, no. 1 (1992).

Since Soviet submarines had achieved more effective quieting and there were fewer sounds propagating via ocean sound channel conduits to be detected by IUSS, subtlety had become obsolete…it was time to break some china. Where there was a dearth of passive noise radiated by Soviet submarines, it was possible to make some. Active sound sources at low frequencies could transmit pulses over great distances that would echo from targets and return signals via the same extended acoustic paths that had carried the earlier Soviet sonic indiscretions prior to their sudden conversion into naval librarians. In 1985 the Chief of Naval Operations initiated a program known as the CNO Urgent ASW Research and Development Program (CUARP) which emphasized active low frequency acoustics - and the U.S. Navy embarked on the development of Low Frequency Active Sonar (LFAS) that in the intervening years has simultaneously become both silver bullet and albatross to present day naval antisubmarine warfare operations.

Almost all of the pieces for an effective low frequency active sonar system existed in inventory when the Navy turned its attention to LFAS as the key to the quieter Soviet submarine problem. The idea had existed in theory for more than a decade and in a subtly different form even had drawn the ire of a group of scientists at the 20th Pugwash Conference in 1970 who were opposed to the undermining of the invulnerable nuclear deterrent by making the ocean transparent by means of acoustics. While the scientists abhorred nuclear weapons they felt that, "As long as the superpowers insist on maintaining deterrent forces, there is great advantage in their [the deterrents] being as invulnerable as possible, since any suggestion of vulnerability seems almost certain to lead to an effort to compensate for that real or imagined vulnerability with the result being an expanded arms race."[19] At a time when the United States still enjoyed significant acoustic advantage over the Soviets – *before this lopsided advantage had been sufficiently revealed* – it was not necessary to pursue such an exhaustive system and affect the arms race in a manner that the Pugwash scientists feared, and the specific "sonar phased array" project that had drawn their ire was shelved.

The decision not to pursue a technique purported to make the oceans transparent did not however quell apprehensions altogether among those concerned for the perilous equilibrium of Mutually Assured Destruction. Concern for destabilizing the strategic submarine deterrent even extended to the notion that

[19] Anthony Ripley, "Peace Scientists Oppose Submarine-Finding Device," *New York Times*, September 17, 1970.

antisubmarine warfare techniques should be pursued only to the extent that attack submarines – the type of submarine that targeted surface vessels and other submarines – were capable of being targeted while techniques that might detect missile boats should be avoided; discrimination would be achieved as a result of tactical differences in operating characteristics.[20] While the United States enjoyed a substantial lead in the underwater acoustic contest, a certain element of academic argument over deterrence theory was acceptable. But with the sudden deterioration of the acoustic advantage in the mid-1980s, such magnanimous views were dropped; apparently invulnerable (Soviet) second strike capability was not quite so amenable when it actually was invulnerable.

More deliberate means of submarine detection were necessary and low frequency active acoustics received immediate attention. The Navy had already deployed the passive low frequency Surveillance Towed Array Sonar System (SURTASS) on a specialized geodetic oceanographic survey ship designated T-AGOS by the mid-1980s. This passive towed array together with the seabed Sound Surveillance System (SOSUS) arrays formed the Integrated Undersea Surveillance System (IUSS) and between them these fixed and mobile arrays effectively comprised the receiver modules that would be required for an active low frequency system. What was still necessary then was a sufficient low frequency source, and this in effect was the reverse problem faced by Professor Fessenden some four-score years earlier when he attempted to scale down his oscillator to obtain higher operating frequencies and more manageable shipboard devices. The solution was not a small affair. The experimental low frequency source developed for the initial Critical Sea Test (CST) under the CUARP weighed fifty tons and required one megawatt of power-generation capacity.[21] A specialized ship was constructed to handle such an unwieldy hydrophone array and the U.S. Navy quietly (!) began a program of operational testing of low frequency active sonar to combat the threat of quieter Soviet submarines.

The development of Low Frequency Active Sonar (LFAS) - also referred to as Low Frequency Active Acoustics (LFAA) - proceeded steadily but did not reach operational status before the end of the Cold War.

[20] Richard L. Garwin, "Antisubmarine Warfare and National Security," *Scientific American* 227, no. 1 (1972).
[21] Tyler, "The Emergence of Low-Frequency Active Acoustics as a Critical Antisubmarine Warfare Technology," 154.

By 1992 the Navy had completed a series of initial sea trials utilizing the research platform *R/V Cory Chouest*, a pipe ship that had been especially converted to conduct the LFAS testing. Still focused on the Soviet paradigm of progressively quieter nuclear submarines operating in the open ocean, the *Chouest* tests took place "in the Navy's highest priority geographic areas" which at that time included the "Norwegian Sea, the Icelandic basin, the Hatteras Abyssal Plain, the Mediterranean Sea, and the Gulf of Alaska." The tests were not small affairs; they included simulated targets, environmental support from oceanographic ships, and in some instances warships and maritime patrol aircraft coordinating with the sonar experiments. The passive exploitation of low frequency sound was different than the use of an active source, so early tests examined the influence of "reverberation from the surface, bottom, and volume as the most important areas at issue for low frequency-active acoustics."[22]

Although the early testing took place at a time when some Soviet submarines still patrolled the seas, there was already an eye to the future, "Since emphasis has been placed on the Soviet threat for the last forty years, Navy research and development in acoustics has concentrated heavily on countering the nuclear submarine in deep-water areas. Research in LFAA including CST, has also been concentrated on deep-water areas. If current geopolitical trends continue, and the U.S. Navy increases the priority of Third World security issues, the research and development community will be designing sonars to meet new threats (e.g. diesel-electric submarines) operating in areas that differ significantly from the open ocean."[23] The LFAS development program planned accordingly, "Phase I of the CST program (1986-1990) concentrated on deep-water issues related to the design of sensors and systems for countering the Soviet threat. Phase 2 of CST (1991-1996) will emphasize shallow-water issues, as well as acoustic warfare. In anticipation of the use of LFAA by many countries, the development of acoustic support measures, countermeasures, and counter-countermeasures is envisioned. Acoustic warfare considerations, similar to the development of electronic warfare for radar, must be built into sonar designs at the earliest stage possible to prevent the rapid obsolescence of LFAA systems."[24]

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[22] Ibid.: 154-155.
[23] Ibid.: 157.
[24] Ibid.: 159.

It is apparent that LFAS was envisioned as the method of the future for antisubmarine warfare – which again was expected to be fought in the coastal shallows – not only for the United States Navy but for other navies as well. The research, design, and testing of such a system is typically one that takes place on the quiet periphery of naval operations, and much of the early work remains classified. Little about the program appeared in print except for in a few specialized technical journals. There was some limited public awareness that the Navy was working on new methods of ASW, but at the time submarine warfare received a lower profile in headlines that were dominated by events such as the Gulf War, Somalia, and Bosnia where very little appeared to involve undersea warfare, and LFAS development proceeded apace outside of general news coverage. At the same time however, an effort to leverage similar principles for different ends would launch LFAS out of the shadows and into the headlines.

Letting the Acoustic CAT Out of the Bag…

The name Walter Munk carries with it a certain reverent deference in present day oceanographic circles, and perhaps especially so among naval oceanographers. A white-haired elder statesman of the science, Dr. Munk earned his status both for his brilliant and meaningful work in the field – he is the same Walter Munk whose work on wave dynamics facilitated the World War II amphibious landings, whose interest and work with the dynamics of tsunamis led to the Pacific Tsunami Warning System, and whose theories on ocean circulation helped explain strong western boundary currents and broad easterly flow[25] – as well as for his unbounded curiosity and his professorial interest in just about anything oceanographic that inquisitors might put before him. His lectures draw an almost oracular interest from students and faculty at the Scripps Institution of Oceanography where Munk spent virtually his entire career and resides now as an *eminent grise* still very much involved in active science.[26] An award that is presented jointly by The Oceanography Society, the Office of Naval Research and the Office of the Oceanographer of the Navy as merited *In*

[25] Joan Brown, Angela Colling, Dave Park, John Phillips, Dave Rothery, and John Wright, *Ocean Circulation*, ed. Gerry Bearman (Milton Keynes: Butterworth Heinemann, 1998), 90-92; "Walter Heinrich Munk Biography," *Histories*, 2003 (accessed August 28, 2006); available from http://scilib.ucsd.edu/sio/archives/siohstry/histories.html.

[26] As a student at Scripps in the late 1980s, and at every opportunity thereafter, the author attended any Munk lecture advertised and confesses to a certain degree of awe for a man so involved at many critical junctures of the science throughout its heyday in the years after World War II.

Recognition of Distinguished Research in Oceanography Related to Sound in the Sea is named for Dr. Munk and bears his likeness on the presentation medallion.[27]

Walter Munk is disarmingly disingenuous, and so obviously interested in and enthusiastic about science and the benefits that knowledge of the oceans might bring to mankind that it is ironic among scientists that he found himself at the vortex of a controversy related to the use of active low frequency acoustics that ultimately carried the Navy program developing LFAS with it into a maelstrom of public furor. Munk's sin in this case was that he wanted to investigate the possibility that the oceans might be warming as an element of global climate change. Familiar with the daunting task of explaining ocean processes with scant and suboptimal data, Munk envisioned a manner to gather data on mesoscale to basin-wide ranges through near-simultaneous measurement. Initial conceptual experiments met with success, so Munk and his colleagues formulated a more comprehensive test for their investigative techniques. It was here that the program ran awry of unexpected events. Munk and his team filed for the proper environmental permits from the appropriate agencies of the U.S. government. Part of this process involves an opportunity for public comment; while transparency is beneficial for activities of government under a democratic system and not inherently detrimental, it also provides an opportunity for feedback to destabilize a system…and in this instance, legitimate concern for the protection of wildlife was joined to misunderstanding of regulatory terms and conditions – generating intense opposition and suspicion for a scientific program with (ostensibly) unexplained military ties. Amplified through the electronic megaphone of the Internet "blogosphere," the situation grew out of proportion. Sound in the sea was suddenly front page news.[28]

Ocean Acoustic Tomography was the name selected by Munk and colleague Carl Wunsch for a technique that they felt might provide insight into the variability of the oceans by utilizing low frequency sound as a measuring tool. An allusion to the Computer-Aided Tomography (CAT) medical technique that is used to take image "slices" through the human body using x-rays, it was a name that was "deliberately

[27] The Oceanography Society, "The Munk Award," (accessed 2003); available from www.tos.org.
[28] Malcolm W. Browne, "Global Thermometer Imperiled by Dispute," *New York Times*, October 27, 1998.

chosen to arouse the reader's curiosity as to what it is all about."[29] As a harbinger of things to come, inviting curiosity to this CAT was perhaps not the best tack to take, and as the fully expressed aphorism would suggest led to its (near) death as a broad tool for ocean investigation.

Wunsch and Munk were interested in examining processes of the ocean mesoscale, and devised the tomographic method "in direct response to the demonstration…that about 99% of the kinetic energy of the ocean circulation is associated with features that are only about 100 km in diameter."[30] Persistent on time scales of around 100 days, mesoscale features are difficult to sample, but are important to physical oceanographers for their role in ocean mixing processes, air-sea interactions, and climatic events such as El Niño. To adequately investigate the parameters of interest of this temporal and spatial variability *in situ*, equipment would have to be placed at every 50 kilometers at grid points throughout the area of interest and remain there for many months. Some 400 moorings would be necessary to study a region 1000 kilometers square; by the late 1980s and early 1990s when the technique was first tested over basin scales, only about 50 such moorings were deployed annually worldwide.[31] Altimetric measurements by satellites offered some promise when ocean acoustic tomography was first proposed, but despite their utility at providing a surface view of the oceans these newly orbiting sensors were considered complementary rather than substitute measurements; instead of relying on proxies that could be modeled to depth - as would be the case for altimetric measurements – the scientists felt that "there will always be a need for interior measurements of the oceans."[32]

Since investigating the oceans on megameter scale (1000 kilometers) would have required many vessels or hundreds of observational mooring stations; Wunsch and Munk consequently decided the best way to investigate their phenomena of interest would be to use a technique that measured ocean properties *between*

[29] Walter Munk, Peter Worcester, and Carl Wunsch, *Ocean Acoustic Tomography* (Cambridge: Cambridge University Press, 1995), 355.
[30] Ibid., 1.
[31] Robert C. Spindel and Peter F. Worcester, "Ocean Acoustic Tomography," *Scientific American* 263, no. 4 (1990): 94.
[32] Walter Munk and Carl Wunsch, "Ocean Acoustic Tomography: a Scheme for Large Scale Monitoring," *Deep-Sea Research* 26, no. 2A (1979).

rather than *at* observation stations.[33] It was a novel approach, but that derived from earlier work in the field. An experiment conducted years earlier to investigate low frequency propagation of sound had provided the first cues; over a period of more than two years of the Sound Channel Axis Velocity Experiment (SCAVE) from 1961 through 1964 between Bermuda and the Bahamas, scientists had noted significant variability in the travel time for sound waves between fixed positions – variability that was path dependent between different arrays. With a greater appreciation for the presence and importance of mesoscale variability for ocean dynamics in this region after the 1972 Mid-Ocean Dynamics Experiment (MODE), Munk and Wunsch realized that the earlier observations were consistent with sound speed deviations explainable by variable mesoscale features that were persistent throughout the area. Years later when the technique would run into trouble as a matter of scientific inquiry, it was while investigating longer term climatic signals in the oceans but ocean acoustic tomography began as a tool to study mesoscale parametric variability – the "weather" of the ocean as opposed to "climatology" - with sound.[34]

The essential rationale behind ocean acoustic tomography is the same principle that was visited earlier in discussions of sonar and sound propagation with respect to ocean structure. Sound speed varies in the ocean with temperature, salinity and pressure; and sound rays refract as they propagate according to variations in these parameters. With sources and receivers placed in varying geometries, acoustic signals can be made to travel various paths between instruments in order to "deduce the properties of the ocean's interior – its temperatures, salinities, densities, and current speeds – on the basis of how the ocean altered the signals."[35] All underwater sound is attenuated with spreading and absorption effects once it travels any distance from its source, but this is especially the case for higher frequencies; low frequency sound, by comparison travels much greater distances through the oceans and under the right "ducting" conditions can travel thousands of miles. As discussed earlier, it was the discovery of the transparency of the oceans to certain low frequency transmissions via "ducts" that became known as sound channels that was the basis for the SOSUS hydrophone arrays that were used effectively against Soviet submarines throughout the Cold War.

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33 Munk, Worcester, and Wunsch, *Ocean Acoustic Tomography*, 1.
34 Munk and Wunsch, "Ocean Acoustic Tomography: a Scheme for Large Scale Monitoring," 123, 127-128.
35 Spindel and Worcester, "Ocean Acoustic Tomography," 95.

Not unexpectedly, while investigating methods of acoustic tomography scientists concluded that low frequencies were the key to sampling the ocean effectively over mesoscale (or longer) distances with sonic techniques. Aside from achieving the required ranges by using low frequency sound, there was another benefit, "The deep sound channel not only produces ducted propagation – the basis for long-range sound transmission and reception – but also causes sound waves that radiate at different angles to travel along distinct, separate paths. This multipath propagation – the basis for tomography – samples the vertical plane between each transmitter-receiver pair." Sound waves created near the channel axis would propagate nearly in straight lines, but rays with sharper angles would trace nearly sinusoidal paths though the duct; although rays following sinusoidal paths travel further, they generally travel faster and arrive earlier at receivers - providing for different signal arrival times and characteristics for difference techniques to glean parametric information from their comparison in order to infer something about the state of the ocean along each particular path of travel.[36] Adding sources and receivers in a test area multiplies the number of possible paths, greatly enhancing the amount of information that can be gleaned through tomographic techniques - something that was always of importance given the expense of conducting ocean surveys with advanced technologies that were not immune to the harsh environment of the seas. In summarizing the advantages of tomographic techniques, Munk and Wunsch wryly noted that "This quadratic information growth [with additional sources and receivers] is an attractive feature (though the quadratic loss with instrument failure is not)."[37]

A series of ocean acoustic tomography experiments were conducted not long after Munk and Wunsch published their projections for employing the technique in the late 1970s, views which were decidedly optimistic, "Our fundamental conclusion is that there are no barriers, theoretical or practical, to large scale acoustic monitoring of the ocean. At the present time we need field data to confirm in practice that we can identify and keep track of the different multipath arrivals and that our noise estimates are correct. Tomographic systems may also be useful in regions of high currents (like the Gulf Stream), where conventional mooring techniques are unequal to the environment. We are intrigued with the almost

[36] Ibid.: 96-97.
[37] Munk, Worcester, and Wunsch, *Ocean Acoustic Tomography*, 2.

unlimited number of possibilities for future development."[38] Investigating the same region of the Northwest Atlantic that the MODE surveys earlier had shown to be highly variable on the mesoscale, one of the first tomographic efforts was quickly rewarded in 1981. A 90,000 square kilometer "snapshot" of the ocean was obtained in one day during the Tomography Demonstration Experiment, while a concurrent effort by a research ship took three weeks to gather data across the same area – the quality of which "because of the long 'exposure' time, was blurred by the changing mesoscale field."[39]

Subsequent research in both the Atlantic and Pacific revealed the utility of acoustic tomography for resolving mesoscale features and for gathering data on heat content, tides, currents and vorticity. Experiments in the Arctic also showed promise: the 1984 Marginal Ice Zone Topography Experiment in the Fram Strait demonstrated the utility of acoustic tomography at the ice boundary; and the Greenland Sea Project 1988 measured heat content, barotropic currents, and tides in the Arctic, and observed the evolution of deep mixing processes in the Greenland Sea. For a decade after Munk and Wunsch encouraged the use of acoustic tomography, oceanographers pushed their new technique for insights around the globe. Longer arrays were used to gather data for incorporation into numerical ocean models for both nowcasting (synoptic analysis) and forecasting of ocean parameters. Taking advantage of Navy instrumentation already in place located offshore Hawaii and California, near basin-scale tomography was proved tenable.[40] As scientists moved beyond the mesoscale with tomography, it became apparent that something else was possible; by taking enough measurements over long ranges in the oceans and *subtracting* out the mesoscale variability that they originally had sought to investigate, "…ocean acoustic tomography in principle should also be able to measure the temperatures of most of the world's waters simultaneously. Such a feat may provide clues to global warming."[41] Munk, one of the "founders" of the technique, would be in the vanguard of this effort through an ambitious program that would bind military and civilian oceanographic assets together for a worthy cause; but when the situation began to unravel, both civilian and military oceanographic efforts to leverage underwater sound became caught up in the fallout.

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[38] Munk and Wunsch, "Ocean Acoustic Tomography: a Scheme for Large Scale Monitoring," 154.
[39] Spindel and Worcester, "Ocean Acoustic Tomography," 99.
[40] Victoria Kaharl, *Sounding Out the Ocean's Secrets* (Washington, D.C.: National Academy of Sciences, 1999); Munk, Worcester, and Wunsch, *Ocean Acoustic Tomography*, 374.
[41] Spindel and Worcester, "Ocean Acoustic Tomography," 99.

The Herd (Mentality) After Heard…

At 53°06' South latitude and 73°32' East longitude, Heard Island is effectively in the middle of nowhere. In the extreme southern reaches of the Indian Ocean, it is closer to Antarctica than it is to any other continent and so remote that if not for a development in the middle-1800s that sought to improve the safety and efficiency of navigation might have remained in quiet isolation for decades before its icy shores were first recorded in a note by a passing sea captain. Having compiled enough data to make recommendations for long distance sea voyages, Lieutenant Matthew Fontaine Maury of the U.S. Navy recommended an alternate route to one then preferred by Captains sailing from the Atlantic to Australia in the early 1850s. Instead of rounding the Cape of Good Hope and making their way eastward somewhere between 32° and 39° South latitudes, Maury instead recommended that Captains seek the strong westerlies between 50° and 55° and make better time on their voyage.[42]

Onboard the bark *Oriental*, merchant Captain John Heard decided to test Maury's theories while on a run from Boston to Melbourne in 1853. In her journal, Captain Heard's wife Fidelia wrote on 25 November, 1853 that, "At 10 O'Clock the Captain was walking on deck and saw what he supposed to be an immense iceberg. But the atmosphere was hazy, and then a heavy snow squall came up which shut it out entirely from our view. Not long after the sun shone again, …We were all the time nearing the object and on looking again the Captain pronounced it to be land. The Island is not laid down on the chart, neither is it in the Epitome, so we are perhaps the discoverers."[43] It was a forbidding place, home to large and noisy elephant seals which became the main attraction for vessels to venture stopping at its shores. Over the next three decades, the main visitors to the island were sealers, although notably the *HMS Challenger* made an appearance in 1874 on its landmark oceanographic cruise around the world. A few South Pole expeditions made stops on their way to Antarctica in the early 1900s, and the Australian National Antarctic Research Expedition (ANARE) maintained an outpost there from 1947 through 1955.[44] Thereafter Heard Island existed in relative calm with elephant seals ruling its icy shores, until an ocean scientist in the late 1980s

[42] Maury, *Maury's Sailing Directions*, 589.
[43] Quoted in Max Downes, *ANARE Research Notes 104: First Visitors to Heard Island* (Kingston: Australian National Antarctic Research Expedition, 2002), 16.
[44] Ibid., 55.

thought that the location might be ideal for a test of a newly developed technique for measuring parameters of the ocean over basin wide scales…a technique known as acoustic tomography.

"The motivation for the Heard Island Feasibility Test (HIFT) arises from the problem of global warming."[45] So begins the report from the principle investigators of the initial experiment intended to validate the coherent transmission of acoustic signals over basin-wide scales in order to examine ocean climate. Having successfully employed acoustic tomography to study mesoscale variability in many oceans, Walter Munk and his colleagues were ready to move further with their technique and to tackle one of the most formidable environmental challenges of the age. Funded jointly by four U.S. agencies – the Department of Defense through the Office of Naval Research, the National Science Foundation, the Department of Energy, and the National Oceanic and Atmospheric Administration – Munk described the effort as a "slightly mad scheme" that "might flop terribly" but that also might answer the question posed by an article in *Science* that described the effort, "What's the Sound of One Ocean Warming?"[46]

Although signal coherency may have remained a question in order to obtain the type of information scientists desired to study climate, the fact that low frequency sound could travel across ocean basins was not really in dispute. Besides the dynamite fishing technique that investigated the SOFAR channel in the 1940s, other large sound sources had been used in the oceans to measure sound at long distances, including an underwater nuclear explosion known as WIGWAM that was detonated well off the California coastline in May 1955 and which constitutes possibly the loudest sound that man has ever introduced into the water column; echoes form WIGWAM were received from island chains and other topographic features around the vast reaches of the Pacific. Other explosive tests were conducted by dropping Signal Underwater Sound (SUS) charges from airplanes, including as an experiment that dropped eighteen explosive packages on a line from Cape Town to Perth in 1964 with sound received by listening posts more than 10,000 kilometers away.[47]

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[45] Walter H. Munk, Robert C. Spindel, Arthur Baggeroer, and Theodore G. Birdsall, "The Heard Island Feasibility Test," *Journal of the Acoustic Society of America* 96, no. 4 (1994).
[46] Quotes in Ann Gibbons, "What's the Sound of One Ocean Warming?," *Science* 248, no. 4951 (1990).
[47] Munk, Worcester, and Wunsch, *Ocean Acoustic Tomography*, 328-334.

Additional opportunities – not quite “natural” experiments, but at least opportunities that were not entirely wasted – arose when excess munitions were disposed of through underwater detonation in an operation known as CHASE (Cut a Hole And Sink ‘Em) in 1966. Underwater explosions produce sound that can be used experimentally for transmission tests such as those described, but sound from explosive sources is created across a broad range of frequencies which does not provide a clean signal that optimizes the transmission of information that can be gleaned from parameters other than arrival time, something that requires some level of control over the source frequency, duration and intensity. The SCAVE experiments between Bermuda and the Bahamas went a long way to verifying the usefulness of long distance tomography since more information could be garnered from transmissions by a coherent source, but improvements in sound source designs were expected to produce even more useful information from the received signals. The HIFT was something that sought to do just that, and to accomplish it over ocean basin scales in order to establish a baseline for climate studies.[48]

Dr. Munk’s selection of Heard Island to test the feasibility of long distance acoustic tomography did not arise because of a desire to limit any potential damages from such a test to a remote outpost inhabited only by seals. Instead it was the possibility that a test from this location might provide measurable signals across multiple ocean basins; Munk anticipated that sound would be received in Brazil, Africa, New Zealand, Tasmania, Perth, Indonesia, Antarctica, Hawaii, and in locations on the East and West Coasts of North America, “I thought it was intriguing – the idea that you could be on both sides of North America and hear a source of sound on the other side of the world.”[49] It was evident for Munk that this was basic exploratory science, and of a type that might provide immense benefit for mankind if it proved as useful as he theorized for the study of climate through ocean acoustic signals. Other than some professional scientific criticism from colleagues – a matter of course and expected for the good of the science – Munk and his team did not expect to weather public criticism over their intentions which were rather well publicized in the leading scientific journals through articles updating the status and goals of the project. With climate change climbing rapidly on the worldwide agenda in the early 1990s, a scientific endeavor to characterize it definitively in the oceans had merit, and within the oceanography community Munk’s

[48] Ibid.
[49] Gibbons, "What's the Sound of One Ocean Warming?."

imprimateur carried weight as well. At one point Munk and two other proponents of tomography, Carl Wunsch and Peter Worcester, remarked that (after a comparison with the medical procedure known as the CAT scan) their technique was comparably controversy-free, “Unlike medical practice, there is no objection to using intrusive methods to establish the ocean reference state.”[50] In actuality, the era of ocean investigations independent of outside scrutiny or concern had ended, as the HIFT scientists were to soon find out.

The Heard Island Feasibility Test was carried out in January 1991. Coded signals were transmitted from a sound source near Heard Island to sixteen listening stations as far as 18,000 kilometers away in the North and South Atlantic Oceans, the North and South Pacific Oceans, the Indian Ocean and the Southern Ocean near Antarctica. Scientists from Australia, India, South Africa, France, Russia, Japan, Canada and New Zealand provided fixed and towed acoustic array support to the experiment. The test affirmed that phase-coherent processing of low frequency signals transmitted over global ranges could yield enough signal-to-noise excess to provide useful information for tomographic purposes.[51] The overall effort was a success, but an issue that arose near the very end of the planning stages foreshadowed future problems, even if there was little indication from the outcome of efforts during the HIFT. Concern over the potential for harming marine mammals with intense underwater sound required the addition of a last minute permitting process by the U.S. National Marine Fisheries Service and the Australian counterpart organization. Application for and receipt of such permits for ocean experiments often was considered somewhat perfunctory, and when the research vessels sailed they did so without the necessary paperwork. While a failure to obtain the permits would have interrupted the work, final authorizations eventually were received in time – the day before the experiment began!

An *ad-hoc* marine mammal protection scheme was devised to ensure that nearby animals were not adversely affected by the HIFT source. A second ship, *R/V Amy Chouest* was contracted to conduct biological observations, and a team of nine American and Australian biologists embarked to investigate for impacts on marine mammals from the sound transmissions in the vicinity of Heard Island. No aerial

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[50] Munk, Worcester, and Wunsch, *Ocean Acoustic Tomography*, 28.
[51] Munk, Spindel, Baggeroer, and Birdsall, "The Heard Island Feasibility Test," 2330.

observations were available because of the remoteness of the site, but shipboard observations were made throughout the experiment. "Within these experimental limits there was no indication of any harmful effect on the abundant local marine life, although changes in behavior were observed. The most compelling evidence was the absence of sperm whale "clicks" during the transmission period, but there was no accompanying evidence of mammal distress and none of the behavioral changes observed have been associated with long term effects. We had agreed on a protocol whereby a transmission would be aborted if any marine mammals were within 1 km of the source ship at transmission start time. There was no such instance."[52] While they proved to be something of last minute logistical obstacles, the marine mammal observation and mitigation strategies were not onerous and were in keeping with environmentally responsible stewardship expected of ocean scientists; in the end for the HIFT, they were merely speed bumps on the road to success. The way appeared open for more directed testing of Munk and Wunsch's ocean acoustic tomography.

Before considering the next main event in the development of acoustic tomography as an oceanographic technique, it bears consideration that the Heard Island Feasibility Test embodied something of a Cold War collaboration of ocean science and naval oceanography in its most synergistic and mutually beneficial form – even as that conflict was in its waning days. The Navy had embarked on an ambitious program to investigate once more the transmission of low frequency sound in the oceans, and this time rather than just investigating the passive reception of signals, was interested in the active production of low frequency sound to obtain returns from quiet targets. Civilian oceanographers like Walter Munk were coincidentally interested in using active low frequency signals, but instead of looking for submarines as the sounds refracted through the oceans wanted instead to determine fluctuations in the heat content of the waters through which the signals traveled in repeated transmissions. For years Munk and Wunsch had served as members of the JASONs, a little discussed but eminent group of university professors that have been paneled periodically since the 1960s to provide advice to the Department of Defense. It was Munk and Wunsch's work with the JASONs that indicate some of their earliest ideas of acoustic tomography.[53]

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[52] Ibid.: 2332.
[53] Munk, Worcester, and Wunsch, *Ocean Acoustic Tomography*, 355.

Munk's accomplishments in naval oceanography are legion and have been discussed earlier, but it is evident that his access provided him opportunities that he was not shy of leveraging outside of primarily Defense-related applications – and such was the case with the HIFT. The scientists at Heard Island were able to utilize the research vessel that the Navy had overhauled to do its low frequency work, *R/V Cory Chouest*, as well as Navy-owned HLF-4 transducers to serve as their sound source. What is more, Navy SOSUS listening stations served as receivers in Bermuda and along America's Atlantic and Pacific coastlines. To be sure, HIFT became an international collaboration when scientists from other nations joined the effort and provided listening outposts at various locales around the periphery of the world's oceans, but this does not deemphasize the close collaboration that took place between the U.S. civil oceanography community and the U.S.Navy. It should come as little surprise that later when environmental opposition arose over the use of low frequency sound to study the oceans, some opponents considered the scientists to be conducting their experiments in collusion with "secret" Navy research. While "secret" research was not the apparent focus of HIFT or the subsequent acoustic tomographic efforts undertaken by Munk and his colleagues, it would be hard to rule out both the dual-use aspects of some of what was learned about the transmission of low frequency sound, or to deny Navy sponsorship and participation in civilian efforts ostensibly outside of the security realm.

When Walter Munk and colleagues regrouped after the Heard Island Feasibility Test had demonstrated the capability of their technique, it was under a new banner that reflected a slight nomenclatural shift. Acoustic tomography was now called acoustic *thermometry* to reflect the emphasis on the search for a temperature signal when "listening" to "hear" if the oceans were warming. Munk's new proposal carried the title Acoustic Thermometry of Ocean Climate (ATOC) and was part of the Acoustic Monitoring of Global Ocean Climate (AMGOC) program jointly sponsored by the Strategic Environmental Research and Development Program (SERDP) and the Advanced Research Projects Agency (ARPA). The goal of the AMGOC was to "accurately measure ocean temperature on a global scale…[in order to] provide direct evidence of the rate of global climate change." As the flagship experiment of this effort, ATOC was designed to "measure the transmission time of acoustic pulses from source to receiver, deriving the temperature along the transmission path from the speed of sound in the ocean. This method provides

temperature measurement over large ocean expanses and can shorten the time scale for characterizing greenhouse trends to a decade, far shorter and more affordable than methods of atmospheric measurements."[54]

The glossy brochure produced by the ATOC Project Office was as enthusiastic and filled with expectation as it was with vibrant pictures of the ships, gear and the expected graphical color-coded geophysical depictions of the oceans that would result from the effort. Rows of colorful flags instructed the reader that ATOC would be an international effort. An elephant seal lolling among penguins (on Heard Island) and a whale breaching along a lush coastline were shown along with a brief description that a concurrent biological study would be part of the ATOC effort to provide insight into how the sounds might affect marine mammals during the experiment and how man-made sound in general might affect mammal behavior over the long term. The team of researchers from many universities made no excuses for their collaboration with naval interests in their efforts, "With the support of the U.S. Navy, technology is now ready for affordable and reliable sound sources, large hydrophone arrays, and seabed signal processors and recorders. ATOC acoustic sources are planned for installation in waters off the Hawaiian Islands and northern California. The U.S. Navy will also provide extensive access for special ATOC diagnostic receivers at their existing undersea facilities at sites throughout the north Pacific. A data network will process and consolidate special acoustic signals for access by project scientists and researchers through the program's international network."[55]

The ATOC team had selected the "Pacific ocean paths, not because they are climatologically interesting (they are not), but because of the ready availability of Navy acoustic receivers [and facilities]…located at Whidbey Island, Ford Island, Guam, Point Sur, and several other existing facilities depending on Navy SOSUS consolidation plans." Despite being facilities of opportunity, the geographic span of Navy assets provided a still useful venue for tackling shorter term "noise" in the climate signal because of the presence of ocean features, "The resulting North Pacific network configuration would then address seasonal, gyre-

[54] Cynthia Rogers, David Hyde, Lisa Barnhouse, and John Dobyns, *Acoustic Monitoring of Global Ocean Climate* (La Jolla: Scripps institution of Oceanography, 1993).
[55] Ibid.

scale, polar-front, and mesoscale variability issues with about equal emphasis."[56] In the few years that had elapsed since the Heard Island Feasibility Test until the genesis of ATOC, the Cold War had ended; swords were being beaten into plowshares and the Navy's SOSUS stations were earning their keep through dual-use of civil as well as military application such as a well-publicized project for whale studies that began in 1992, and that now were proposed for utilization in climate studies.[57] At a time with such active collaboration between civilian and naval oceanography for their somewhat related but decidedly different goals, it may have been impossible to discern that this fundamental and apparently magnanimous shift in outlook to share what had been one of the nation's most highly guarded secrets would initiate feedback that harbored less auspicious outcomes for both Navy and civilian efforts to harness underwater low frequency sound.

After the Heard Island Feasibility Test proved that basin-wide transmissions of coherent signals made acoustic tomography a technically feasible concept, ATOC was designed to get beyond the mechanics to the ocean science of the problem. It was not necessary to conduct this phase over the same ranges as HIFT, so the ATOC team instead focused on 5,000 to 10,000 kilometer ranges that they considered acoustically feasible and appropriate for the study of climate variables. It was decided that two sources would be utilized: one placed on the seafloor near Kauai that would broadcast northwards towards the Gulf of Alaska, and the other off the coast of California with a northwesterly view of the Pacific towards Japan and a southwesterly aperture towards a receiver that would be placed near New Zealand.[58] The ATOC researchers designed two sound sources that would operate at a much lower intensity than the one used at Heard Island and that operated at slightly higher frequencies. The Heard Island experiment had transmitted at 57 Hertz "to avoid confusion with the ubiquitous 50- and 60-Hz power frequencies" of European and American electric grids.[59] The sources for ATOC were designed to operate between 60 and 90 hertz, transmitting nominally at 75 hertz. The sound source at Heard Island had been an extremely powerful

[56] David Hyde, "ATOC Network Definition," in *OCEANS '93: Engineering in Harmony with Ocean* (Victoria: Institute of Electrical and Electronics Engineers, 1993).
[57] Joint Oceanographic Institutions ad hoc Committee, *Dual Use of IUSS: Telescopes in the Ocean* (Washington, D.C.: Joint Oceanographic Institutions, 1994); Kaharl, *Sounding Out the Ocean's Secrets*.
[58] Munk, Spindel, Baggeroer, and Birdsall, "The Heard Island Feasibility Test," 2341.
[59] Ibid.: 2334.

affair that operated above 220 decibels, while the ATOC sources – required to transmit over shorter ranges – were designed to operate at 195 decibels.[60]

It is important to note that a decibel (dB) is a relative term and requires a reference to make comparisons between different measurements. Only when the same reference is used can direct comparisons be made; for example, the roughly 30 dB difference in power between the HIFT and ATOC sources (both made using a standard reference for sound in water and based upon a logarithmic scale) means that the HIFT source was approximately 1000 times as powerful as the ATOC sources. These types of comparisons are not applicable between measurements made with different references and can (did eventually!) cause considerable confusion when the terms are used to provide analogous comparisons for audiences not familiar with the technical aspects of scientific and engineering programs and terms. In water the standard reference for measuring sound intensity is to compare the signal to one micropascal of pressure at a distance of one meter from the source (1 μPa / 1 m), while in air intensities are measured relative to 20 μPa; this means that a pressure level of 0 dB in air would be measured as 26 db in water. An additional source of confusion with regards to measurements of this sort relates to intensity *produced* at a sound source versus intensity *received* a given distance away at which point sound has attenuated because of spreading and absorption effects.[61] A person ignorant of these factors or that is being intentionally disingenuous can propagate substantial confusion by making apples and oranges comparisons about subjects which inspire passionate audiences and advocacy – such as threats to wildlife and the environment - a factor that became of particular significance as ATOC moved forward.

"If one wants to have a maximum impact on the rate of learning, then one needs to stick one's neck out at an early time."[62] Walter Munk likely did not think that he was following this motto with his advocacy for ATOC other than among his scientific peers who may have lay in wait with various academic slings and arrows for his hypotheses and methods. But Dr. Munk was in for a surprise; both he and ATOC soon came

[60] Eugene H. Buck, *Acoustic Thermometry of Ocean Climate: Marine Mammal Issues* (Washington, D.C.: Congressional Research Service, 1995), 95-603 ENR.
[61] David M.F. Chapman and Dale D. Ellis, "The Elusive Decibel: Thoughts on Sonars and Marine Mammals," *Canadian Acoustics* 26, no. 2 (1998).
[62] Quoted in Janet Howard, "Listening to the Ocean's Temperature," *Explorations* 5, no. 2 (1998).

under concerted attack from an entirely different sector: environmentalists and nongovernmental organizations that were concerned about marine mammals. The sequence of events demonstrates something of the power of public awareness of environmental issues, (mis)information and communication, and of the leveraging aspects of a newly enfranchised electronic community of Internet correspondents. Had the scientists tried to "sneak by" with a program potentially injurious to marine life, the uproar that ensued over ATOC would have been of no surprise. But it is ironic that everything that transpired occurred *because* the ATOC scientists were attempting to follow appropriate guidelines for environmental stewardship while conducting experiments that they felt held significant benefit for other – some might argue greater - environmental concerns.

Acting upon the lessons learned after the permitting requirements for marine mammal considerations nearly derailed the HIFT at the last moment, the ATOC team applied in advance for permits from the National Marine Fisheries Services (NMFS) under the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA).[63] There was little reason to expect any problems…no significant mammal impacts had been noted during the HIFT; the ATOC sources were orders of magnitude less intense; and the ATOC program had incorporated these biological concerns and considerations in their experiment design by including plans for a Marine Mammal Research Program (MMRP).[64] But part of the NMFS permitting process was a period for public comment, and it was during this part of the process that ATOC encountered a barrier more impervious than a strong thermocline to their intended transmissions. "ATOC and its scientists ran into the whale lobby, a political force to reckon with in the late twentieth century, especially in nature-loving California. The debate became extraordinarily bitter, at times hysterical. Rock stars wailed. The Santa Monica City Council condemned the experiment. Environmental groups – including the Humane Society, the Sierra Club, Save the Whales, Save Our Shores, the Great Whales Foundation, the Enemies of Pollution, the Environmental Defense fund, the American Oceans campaign, the Earth Island Institute, and the Natural Resources Defense Council – fought ATOC hard. A wave of angry letters crashed down on attentive congressmen and government bureaucrats. The charge was that ATOC

[63] Buck, *Acoustic Thermometry of Ocean Climate: Marine Mammal Issues*.
[64] Brian Dushaw, "Acoustic Thermometry of Ocean Climate (ATOC)," January, 2003 (accessed June 26, 2006); available from http://staff.washington.edu/dushaw/atoc0.html.

threatened to harm whales and other marine mammals, to render them deaf in a world where hearing is synonymous with survival, with finding food and avoiding becoming someone else's meal. 'A deaf whale is a dead whale,' Lindy Weilgart, a scientist who led the protests, said with characteristic bite. 'It's not worth the risk.'"[65]

Against this unexpected onslaught, the ATOC scientists circled the wagons and sought to inform the public and assuage their fears. "We've been working in the field for years without any problems," Munk explained, and referring to his experience with the HIFT proffered additional assurances, "It [the sound source] was 1,000 times louder than what we want to do now, and we didn't cause any distress to the marine mammals."[66] But when passions become aroused, rational explanations and assurances may not prove to be enough. Confusion abounded over a number of factors: the technologies to be used; the potential danger that existed for marine mammals; ambiguous terminology in environmental protection legislation; and even the "real" reasons behind the program which had been billed as environmentally motivated research to investigate climate change, but became suspect as a military-sponsored "secret" research "conspiracy" as a result of the use of Navy assets as part of the program and because of funding from the Department of Defense's SERDP organization and the Advanced Research Projects Agency (ARPA) – an organization that still existed under a perennial cloud of suspicion in certain circles from its days as the Defense Advanced Research Projects Agency (DARPA) throughout latter half of the Cold War (and a name it has returned to in 2006).[67]

Munk and the other ATOC researchers were caught by surprise. Their program had been discussed in various journals for some time, and had been announced by press releases through Scripps when funds were awarded to conduct the experiments. Environmental permits were not an unfamiliar requirement for marine research, even if in some instances scientists surged ahead without them after overlooking some

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[65] Broad, *The Universe Below*, 313.
[66] Quoted in Philip Yam, "The Man Who Would Hear Ocean Temperatures," *Scientific American* 272, no. 1 (1995).
[67] "ARPA-DARPA: The History of the Name," 2006 (accessed September 03, 2006); available from http://www.darpa.mil/body/arpa_darpa.html; Brent Hall, "ATOC: The Controversy Continues," *Whales Alive!*, 1995 (accessed November 7, 2004); available from http://csiwhalesalive.org/csi95406.html; John R. Potter, "ATOC: Sound Policy or Enviro-Vandalism? Aspects of a modern media-fueled policy issue," *Journal of Environment and Development* 3, no. 2 (1994).

aspect of their research that might have required oversight had environmental impacts been considered in advance. But the ATOC scientists had taken steps to estimate the environmental impacts of their undertaking and applied for the necessary permits. Something had changed the process and made it more volatile…

Trouble began in earnest for ATOC not long after the scientists applied for environmental permits in late 1993. In February 1994, two scientists at Dalhousie University in Canada posted their concerns on the Internet that the experiments might deafen whales, postings that became "amplified and distorted" until the "ATOC researchers were portrayed as inhuman monsters ready to risk deafening more than a half million whales, dolphins, and endangered creatures, crippling and killing them."[68] Two facets of these allegations may be singled out that demonstrate how misunderstanding or miscommunication complicated the issue: the physical power of the ATOC sources to inflict such potential damage, and the estimates for the number of creatures that might be affected. Munk ascribed at least part of the enormous damage estimates that opponents decried to misinterpretation of the source levels that were to be used and to adequate understanding about differences between intensity near the source and that might be received at some distance away. He judged that the marine biology postdoctoral student who had made the allegations that were posted online had overestimated the power of the ATOC sources by six orders of magnitude – one million times![69] That may have made that part of the argument academic, but when the story was picked up and sensationalized by the *Los Angeles Times* with the front page headline reading, "Undersea Noise Test Could Risk Making Whales Deaf," the issue quickly became political and inspired the emotional outcry described earlier.[70]

It was also soon apparent that confusion over the legal language of environmental protection statutes added to the situation when it came to estimating how many animals might be harmed. Under Section 104 of the MMPA, permits were required for "taking" marine mammals in the course of scientific research, a

[68] Broad, *The Universe Below*, 314.
[69] Yam, "The Man Who Would Hear Ocean Temperatures."
[70] Richard C. Paddock, "Undersea Noise Test Could Risk Making Whales Deaf," *Los Angeles Times*, March 22, 1994; Potter, "ATOC: Sound Policy or Enviro-Vandalism? Aspects of a modern media-fueled policy issue."; Yam, "The Man Who Would Hear Ocean Temperatures."

rather vague term that encompassed actions that “harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal,” while the term “harass” was further defined as “any change in behavior by an animal.”[71] The ATOC Environmental Impact Statement had projected that hundreds of thousands of mammals might be “taken” under such parameters, which Munk noted included rather slim margins for violation, “If you turn on your source and a whale changes its course by 10 degrees, you’ve taken him, by definition.”[72] A “take” according to the MMPA definition was not *a priori* evidence of any lasting effects, but in the online opposition to ATOC, however, “take” was not viewed by “bloggers” in the same scientifically objective way…

In a something of a post-mortem analysis, oceanographer John Potter from Scripps viewed what occurred as a confluence of events that were “fueled” by multi-media opinion pieces at a pace that the ATOC researchers were unprepared to match, especially as it unfolded so quickly and unexpectedly. Potter observed that in response to the *Los Angeles Times* article, one online writer interpreted “that the word ‘take’ was ATOC’s euphemism for ‘kill’ and therefore concluded that ATOC expected over 500,000 animals to die…[and]…lambasted the ATOC program, calling it ‘one of the most astoundingly stupid and potentially destructive experiments it’s ever been my displeasure to read about in advance’ and incited the reader to ‘Call everybody you can think of, and then ten more you can’t. You can use E-mail and Congressgrams…’ and perhaps the most crucial sentence ‘Please feel free to redistribute this message – anywhere- you want.’ And they did. The ATOC faxes at the NMFS office alone were piled four feet high. Petitions were begun everywhere from campus cafes to surf shops and protest flooded into elected representatives’ offices. The ATOC team were [sic] away in Washington and did not get back to California to respond until several days later, by which time the damage was done.”[73] Munk and his ATOC colleagues had been prepared to spar scientifically over the merits of their proposal, but they were entirely unprepared for doing battle in the court of public opinion.

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[71] Buck, *Acoustic Thermometry of Ocean Climate: Marine Mammal Issues;* "Marine Mammal Protection Act," in *United States Code* (1972); Potter, "ATOC: Sound Policy or Enviro-Vandalism? Aspects of a modern media-fueled policy issue."
[72] Quoted in Yam, "The Man Who Would Hear Ocean Temperatures."
[73] Potter, "ATOC: Sound Policy or Enviro-Vandalism? Aspects of a modern media-fueled policy issue."

The immediate fallout for ATOC from its public relations debacle was a restructuring of the program. Once the ATOC scientists were heard above the initial din of outrage that disrupted the permitting process, the relative merits of their efforts were more reasonably weighed against the relative risks of the program to marine mammals - but even so considerable concessions were worked out prior to the scientists receiving approvals to move forward with the project. The original proposal included a sound source about 25 miles off the California coast that was located within the Monterey Bay National Marine Sanctuary; this proposal was overturned and the source was instead located further west about 50 miles offshore at the Pioneer Seamount. The Marine Mammal Research Program was expanded and funded at more than 50 percent higher than its original $2.9 million dollar figure. A six-month pilot program was added prior to starting the experiment that would vary transmission rates, times and signal strengths to assess exposure levels to mammals near the Hawaii and California sources. Aerial surveys in the vicinity of both sources and visual surveys at Kauai were designed to examine abundance and distribution of mammals and changes related to operation of the ATOC sound sources. The MMRP also included plans to collect ambient noise data from commercial and recreational vessels, and otherwise acoustically assess the test sites. Marine mammal sounds would be recorded *in situ* and additional research would be investigated related to auditory testing of captive specimens of opportunity. After successfully completing the pilot MMRP, the ATOC sources would be allowed to operate only one day out of four, and for 20 minutes every four hours, beginning transmissions at a lower intensity and "ramping up" over five minutes to allow mammals to move away from the source.[74]

Despite the scope of the research effort and built-in precautions to protect mammal subjects, critics remained wary that the MMRP was inadequate to the task of effectively characterizing the impact of ATOC across a range of marine mammal species and a range of potential impacts, "Since some marine mammals use low-frequency sound in feeding, navigating, and communicating, the potential impact of low-frequency sounds of human origin on these species may range from no impact to subtle changes in behavior, temporary behavioral disturbance, avoidance of important feeding or calving areas, deafness, and

[74] Buck, *Acoustic Thermometry of Ocean Climate: Marine Mammal Issues*, 6, 9-10.

possibly death."[75] From both perspectives – the scientists who designed the research and the environmentalists who questioned it's effectiveness - it was a difficult risk assessment…there was little available data on which to base conclusions. A National Research Council investigation into the state of knowledge and research needs related to low frequency sound underwater released during the permitting process indicated that "there were insufficient scientific data to determine the possible effects of low-frequency sound on marine mammals" and that "many past studies supplied only anecdotal evidence, and lacked data on sound source levels as well as on levels received by the animals."[76] For scientists attempting to discern the effects of low-frequency sound on creatures dependent upon it for various functions in this opaque realm, it was something similar to the blind studying the blind all the while hoping not to destroy the subject's walking stick.

With so much controversy over the potential for inflicting harm on marine mammals dominating any news about ATOC, little is heard about what the program eventually achieved scientifically even in its eventually abbreviated form. Walter Munk and his ocean science partners had intended to gather ten years worth of data to discern what they estimated would be an adequate signal to make a statement about climate change in the ocean. In the end the scientists were left with considerably truncated data records and at present only the limited remnants of what had originally appeared to be a project worth sticking one's neck out… The acoustic source mounted on the Pioneer Seamount transmitted at irregular intervals over three years from 1996 through the end of 1998; it was eventually removed in 2000 after permits expired in 1999 and were not renewed. The Kauai source began transmissions in late 1997 until October 1999, remained dormant for two years and then was reenergized in 2002 as part of a follow-on to ATOC known as the North Pacific Acoustic Laboratory (NPAL); data through the end of 2005 is available online through the University of Washington NPAL program site.

With an initial 15 months worth of data, the ATOC scientists were able to verify that their technique worked "as a method for measuring the average temperature of vast expanses of ocean." Variations of as

[75] Ibid., 2-3.
[76] Ibid; National Research Council Committee on Low-Frequency Sound and Marine Mammals, *Low-Frequency Sound and Marine Mammals: Current Knowledge and Research Needs* (Washington, D.C.: National Academy Press, 1994).

little as 20 milliseconds of travel time over a distance of almost 5,000 kilometers were detected, allowing the scientists to "estimate average ocean temperatures along the signals' pathways to within .006°C." Seasonal signals of approximately 2°C were also detected in the upper oceans in line with climatological expectations. The scientists were also able to examine relationships between sea level heights as measured by satellite altimeters versus tomographic data to determine the proportion of the observed signal that resulted from thermal effects (seawater expands with heat) as opposed to changes that resulted from additions of water or variability in salinity. They determined that in the area of the acoustic paths traveled by ATOC that sea level height proxies for thermal content variability were not as accurate as expected, a result that "calls into question the basic calculations of ocean heat content derived from satellite measurements that are used in computer models to predict future changes in climate."[77] This does not diminish the utility of the altimetry data, but merely reconfirmed Munk's and Wunsch's assertion that tomographic techniques were complementary to other *in situ* and remote sensing data gathering efforts in the oceans – and particularly satellite altimetry because of its horizontal resolution at the surface when paired with the vertical resolution provided throughout the water column supplied by tomography.[78]

The much-stressed Marine Mammal Research Program was completed in tandem with the ATOC experiment, and a follow-on program was stipulated as part of the NPAL permitting process.[79] For all the public outrage beforehand and dire projections regarding "deaf whales," little was shown by way of effect on marine mammals, "The MMRP did not find any overt or obvious short-term changes in the distribution, abundance, behavior, or vocalizations of marine mammals in response to the playback of ATOC-like sounds or in response to the transmissions of the ATOC sound sources themselves. No species vacated the areas around the sound sources during transmissions. Statistical analyses of the data showed some subtle, but statistically significant, shifts in the distribution of humpback (and possibly sperm) whales during transmission periods, as well as some subtle changes in the behavior of humpback whales. The MMRP

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[77] Howard, "Listening to the Ocean's Temperature."
[78] "Acoustic Thermometry of Ocean Climate (ATOC)," 2005 (accessed September 03, 2006); available from http://atoc.ucsd.edu; Browne, "Global Thermometer Imperiled by Dispute."; Munk, Spindel, Baggeroer, and Birdsall, "The Heard Island Feasibility Test," 2341; Munk, Worcester, and Wunsch, *Ocean Acoustic Tomography*, 28, 324, 366.
[79] "Record of Decision for the Final Environmental Impact Statement for the North Pacific Acoustic Laboratory Project," February 11, 2002 (accessed September 03, 2006); available from http://www.epa.gov/fedrgstr/EPA-IMPACT/2002/February/Day-11/i3222.htm.

investigators concluded that these subtle effects would not adversely impact the survival of an individual whale or the status of the North Pacific marine mammal populations."[80] Biologist Christopher Clark, one of the lead MMRP scientists, characterized the sound transmissions as "biologically innocuous" and noted that while slight differences in the distribution of humpbacks and sperm whales were noted, they did not appear correlated to the intensity of the sources. Radio-tagged elephant seals swam by the sources without any indication of avoidance. Clark and other researchers of the MMRP "found more variability in animal behavior was explained by the day-to-day traffic in the harbor and the bay than by ATOC. There were weekends on the Kauai coastline in peak season when helicopters flew over whales 90 times."[81]

With little evidence from directed testing about potential harm from ATOC or follow-on proposals such as NPAL, and a fair amount of data indicating that more common commercial and recreational pursuits might in fact provide more substantial impact, some of the furor over the acoustic affront to marine mammals posed by tomography seems to have died down. When the NPAL permitting process was opened for public comment in 2001, involving the same ATOC acoustic source near Kauai intending to produce sound intensities of 195 dB on the same periodicity as the earlier experiment (for similar goals), only three letters were received: one from the State of Hawaii and one from the U.S. Army Corps of Engineers each declaring no impact, and a third which "pertained to a different Navy proposed action, the Low Frequency Active sonar, an action unrelated to the NPAL project."[82] This last misdirected letter of comment may seem trivial, but the association of ATOC and NPAL as matters of military interest – and subsequently a certain conflation and confusion among critics with other similar but distinct naval efforts – affected their viability as programs. What is more, the Low Frequency Active Sonar effort being undertaken by the Navy during the same timeframe as ATOC became entrained in the same environmentally constrained and emotionally driven vortex, a development that affected the more traditionally security-oriented program significantly…

[80] Dushaw, "Acoustic Thermometry of Ocean Climate (ATOC)," (accessed).
[81] Quoted in Howard, "Listening to the Ocean's Temperature."
[82] "Record of Decision for the Final Environmental Impact Statement for the North Pacific Acoustic Laboratory Project," (accessed).

It <u>Sounds</u> Like the Same Thing…?

In 1994, while enmeshed in the midst of the ATOC controversy, National Research Defense Council (NRDC) attorney Joel Reynolds heard rumors that Walter Munk and the ATOC team were not the only ones investigating uses of low frequency sound in the oceans. Reynolds got wind that the Navy was conducting "top-secret sound experiments off the California coast." He pursued information through interviews and record searches and eventually determined that the U.S. Navy had spent the better part of a decade investigating low frequency sound that could "light up with sound literally hundreds of thousands of square miles of ocean at a time." What is more, he learned "that the Navy had already field-tested LFA sonar in twenty-two operations – but had never studied its effects on marine life. Nor had the Navy applied for the permits required by the Marine Mammal Protection and Endangered Species Acts." Reynold's wrote a letter to the Navy that identified a number of environmental laws that it could be violating through its actions; after six months of further negotiations, the Navy agreed to conduct environmental studies to determine the effects that its low frequency tests might be having on marine life.[83]

A Navy spokesman stated that the Navy's decision to pursue a more formal environmental impact assessment than it had completed for any earlier sonar testing was based upon a decision to move forward to development and deployment of the system.[84] Whether Reynolds "won" or whether he merely paralleled an internal decision that would have been made regardless is for observers to judge. Either way, on July 18, 1996 the Navy published a notice of intent in the *Federal Register* to prepare an Overseas Environmental Impact Statement/Environmental Impact Statement (OEIS/EIS) in accordance with the National Environmental Policy Act of 1969 (NEPA) which applies to federal activities in the United States, and its territories and possessions; and in accordance with requirements of Presidential Executive Order (EO) 12114 (Environmental Effects Abroad of Major Federal Actions) which applies to actions that take place outside of the areas covered by NEPA. Public scoping and outreach meetings were included to inform the public about the intent of the Navy program and incorporate comments and concerns into the

[83] Dick Russell, "Fieldwork: Bad Vibes," 2002 (accessed March 28, 2005); available from http://www.nrdc.org/onearth/02sum/field.asp.
[84] Stephanie Siegel, "Marine Mammal Facts Just Drops in the Bucket," July 01, 1999 (accessed May 25, 2005); available from http://cnnstudentnews.cnn.com/NATURE/9907/01/sea.noise.part2/index.html.

process. As part of its effort to characterize the effects of low frequency sound on marine life, the Navy paneled a Scientific Working Group (SWG) to "address the underlying scientific issues needing resolution for development of this OEIS/EIS;" and an ambitious three-phase biological study known as the Low Frequency Sound Scientific Research Program (LFS SRP) was created that would employ some sixty researchers in collecting field data on the potential effects of low frequency sound on whales. An additional study was sponsored to assess the effects of low frequency sound on divers in order to establish safe exposure limits. Finally, monitoring and mitigation strategies would be developed to prevent and/or minimize exposure of marine mammals to potentially harmful sound.[85] The OEIS/EIS would take five years to complete and represented the first such environmental impact review for a sea-based operational system ever completed by the Navy.[86]

For the American public in 1996, the Cold War was over and already slipping into the distant past. The notion that submarines still presented a threat to American interests was not something easily imagined; after the resounding victory in the 1991Gulf War, the U.S. military appeared unbeatable on the conventional battlefield, and the U.S. fleet was larger than many nations' navies combined. The U.S. Navy therefore had its job cut out for it in identifying a threat potentially worth the lives of some of nature's most well-loved creatures. In the "Purpose and Need" category of the OEIS/EIS Executive Summary, the utility of submarines for coastal defense, surveillance, and special operations missions is described, as well as the fact that the units are stealthy, carry torpedoes and cruise missiles, and are a cheap way for an enemy to muster combat power. The Navy noted that adversary submarines were getting progressively quieter, and that since the end of the Cold War (when passive low frequency techniques had provided for extended detection ranges against less stealthy Soviet nuclear subs until late in that conflict) the range at which submarines could be detected was greatly reduced. With less reaction time to defend against enemy submarines, this could "jeopardize U.S. ability to control the sea, land, air and hinder follow-on offensive and defensive operations. Eliminating this threat to U.S. security and maintaining the Navy's

[85] *Executive Summary: Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar* (Arlington: United States Navy, 2001).
[86] United States Navy, "SURTASS LFA," 2002 (accessed November 11, 2004); available from http://www.surtass-lfa-eis.com/.

antisubmarine warfare (ASW) mission into the future were reasons for developing a long-range sonar technology."[87]

Part of an Environmental Impact Statement is the consideration (and subsequent ruling out) of alternatives to the proposed program which might lessen environmental impact in order to demonstrate the need for such potentially damaging technology. The Navy reported that other acoustic and non-acoustic techniques and technologies were explored – among them "radar, laser, magnetic, infrared, electronic, electric, hydrodynamic, biologic and sonar (high-, mid- and low frequency)" methods - but that only "low frequency active sonar was…capable of providing reliable and dependable long-range detection of quieter, hard-to-find submarines…[and] would meet the Navy's need for improved detection and tracking of new-generation submarines at long range…[and] provide U.S. forces with adequate time to react to, and defend against, potential submarine threats while remaining a safe distance beyond a submarine's effective weapons range."[88] After setting out the reasons that this new technology was important for national security, what remained was for the Navy to explain (convincingly for the environmental groups that opposed the technology) that LFAS could be employed while not threatening the survival of marine mammals and other sea creatures.

After having witnessed the furor over ATOC and the public relations nightmare that program endured when it was pilloried without being able to present its case, the Navy set about the OEIS/EIS process with diligence, and the LFS SRP program that was designed to investigate the impacts of low frequency sound on marine mammals to demonstrate that LFAS would not impact them (too) greatly was multifaceted. First the types of creatures that might be potentially affected were identified; scientific research was devised to estimate the effects of low frequency sound on them including both the potential for injury as well as behavioral modification; methods were developed to quantify risks to marine mammals; and finally various methods for monitoring and mitigation of adverse effects that were identified in the process.

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[87] *Executive Summary: Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar*, ES2-ES3.
[88] Ibid., ES2-ES3, ES6.

A Scientific Working Group was established to oversee the efforts and consisted of representatives from the Office of Naval Research, National Marine Fisheries Service, the Marine Mammal Commission, the Naval Submarine Medical Research Laboratory (NSMRL), Harvard Medical School, an observer from the League for Coastal Protection to represent private environmental groups, and a number of universities and oceanographic laboratories including Cornell, the University of Washington, University of California, Hubbs Sea World Research Institute, Bodega Bay Marine Laboratory, and the Woods Hole Oceanographic Institute. A team of some sixty researchers from the above institutions and from contractors Raytheon and Marine Acoustics Incorporated would work with the Naval Facilities Engineering Service Center, the Point Mugu Outer Sea Test Range and utilize the Navy's low-frequency test vessel, *R/V Cory Chouest* to conduct their experiments. A special Diver Risk Analysis Team was established to investigate and promulgate guidance for safe exposure limits for divers who might be exposed to LFAS and included a number of researchers from the University of Rochester, Georgia Institute of technology, Boston University, the University of Pennsylvania, Duke University, the Applied Research Laboratory of the University of Texas, and the Divers Alert Network together with the Navy's NSMRL and the Naval Medical Center San Diego. With such a far-reaching program of investigation, the Navy hoped to satisfy skeptical observers that due diligence had been applied to determining the effects and mitigation strategies of the LFAS program.[89]

The SRP selected research subjects according to two criteria: presence in the area of operations and the potential for being physically affected by low frequency sound. From a list that included virtually all marine vertebrates and invertebrates, the SRP selected five groups: sharks and rays, bony fish, whales and dolphins, seals and sea lions, and sea turtles. Invertebrates were largely excluded because they did not possess "delicate organs or tissues whose acoustic impedance is significantly different than water" and because there was "no evidence of auditory capability in the frequency range used by SURTASS LFA sonar."[90] Because little data was available on the effects of low frequency sound on humans, an independent study was commissioned that examined acceptable thresholds for Navy divers (assumed to be in good physical condition) and for recreational and commercial divers (not required to maintain equivalent physical standards to Navy divers). From these studies, a damage risk threshold of 160 dB received level

[89] Ibid., ES6 - ES9.
[90] Ibid., ES10.

(over 100 seconds at a 50 percent duty (on/off) cycle and for a cumulative 15 minutes per day) was established as the recommended maximum exposure for divers "who were equivalent in health and fitness to Navy divers." For other divers, testing was designed based upon psychological aversion, and 145 dB of low frequency sound was recommended to be the maximum exposure level without adverse effects – guidance that was "considered a conservative, protective decision."[91]

When it came to researching the effects of low frequency sound on marine mammals, scientists had limited data to work with beforehand. Relatively few species of marine life had been assessed for hearing capabilities; there was limited knowledge of the functions of sound produced by marine mammals; and even less data was in existence on the response of these creatures to low frequency sound. The SRP used modeling techniques to design their studies, and rather than attempt to asses an animal's hearing focused instead upon behavioral responses to exposure to low frequency signals. The SRP also included research to develop "a scientifically reasonable estimate of the underwater sound exposure levels that may cause injury to marine mammals and research on the potential effects of LF sound on marine mammal behavior." Baleen whales (mysticetes) were selected for the studies based upon discussions with "academic scientists, federal regulators, and representatives of environmental and animal welfare groups" because this species was presumed to be the most sensitive to sound in the SURTASS LFA sonar frequency band, were protected under law, and there was prior evidence of avoidance responses to low frequency sound. Mysticetes were determined to "have the best LF hearing of all marine mammals," while the other marine life subject to assessment under the SRP such as pelagic fish and sea turtles and deep-diving species of whales including sperm and beaked whales were determined to be less sensitive and therefore at lower risk than the baleen whales selected for study.[92]

The Low Frequency Sound Scientific Research Program was conducted in three phases between September 1997 and March 1998 off the coast of California and near the Hawaiian Islands. Going into the study, there was a "prevailing theory that a 140 dB received sound level would drive away marine mammals." Consequently, if this proved to be the case, "…then LFA probably would not be deployed or

[91] Ibid., ES11.
[92] Ibid., ES11 - ES13.

would be severely restricted." The goal of the SRP, therefore, was "to demonstrate the avoidance reaction during critical biologically important behavior of sensitive species to the low frequency underwater sound produced by the LFA system." Phase I sought to investigate the effects of low frequency sound on blue and fin whales while feeding and to characterize the whales' reactions depending on the received levels of sound, changes in the received levels, and whether the source was fixed or closing the whales' positions.

Two strategies were employed in Phase I testing to achieve desried effects: the first used a "bottom bounce" technique to estimate the effects on whales from a distant source, and the second used a "direct path" technique to create an omni-directional sound field and simulate an approaching source. *R/V Cory Chouest* served as the source vessel while two independent observation vessels with marine mammal experts onboard were nearby to estimate effects from the testing and to record both the sound signals and whale vocalizations. Aerial surveys were conducted by observation aircraft and seafloor acoustic receivers including SOSUS arrays were employed for additional acoustic analyses. Both full power and reduced transmission powers were used in the Phase I testing. The highest received levels by the four blue whale and fifteen fin whale test subjects were estimated to be between 148 and 155 dB. *No overt behavioral responses were observed.* In addition, there were no changes noted in whale distribution due to LFA operations; instead observed distribution appeared to more closely depend on the availability of food sources. A slight decrease in whale vocalization noted in preliminary analysis of Phase I results was unconfirmed by subsequent analysis.[93] Three months later, the SRP returned to coastal California to conduct Phase II, this time to study the effects of low frequency sound on migration patterns.

California Gray Whales follow a regular annual migration pattern from the Gulf of Alaska to the Sea of Cortez near Baja California. Whale watching boats regularly foray from California ports to observe the great animals, and their migrations occur so close to the coastline that they often can be observed from hillsides along the shore. Phase II of the SRP sought to determine whether low frequency sources located either in the migratory path or seaward of migration routes might alter whale behavior. Again, whale responses to received level were important to researchers, as well as whether whales would respond more

[93] United States Navy, "SURTASS LFA," (accessed).

to received level, sound gradient, or range to the transmitting source. The low frequency sound source was deployed from a research vessel moored off of Point Buchon on the central California coastline. Researchers stationed on the source boat and on an additional monitoring vessel were augmented by shore-based trained observers who were positioned on hillsides to monitor whale responses to sound signals. Scientists were prepared to cease transmission if potentially "worrisome behavioral reactions" occurred or if the whales approached close enough to the source that they might exceed the predetermined upper limit of 155 dB. While the sound source was moored one mile offshore in the middle of the migration route, whales demonstrated avoidance responses but subsequently returned to their migration routes within "a few kilometers." In contrast, when the sound source was moored two miles offshore seaward of migration routes, less response was observed even while the transmitter was elevated to its highest 200 dB source level. Whales that were migrating offshore seaward of the source did not appear to deviate from their migration routes.[94]

Phase III of the SRP shifted studies to the Kona coast of the Hawaiian Islands. There, *R/V Cory Chouest* was once again used to deploy the sound source for testing, this time to investigate the responses of humpback whales. At-sea and shore-based observers were again employed to gather test data when whales were exposed to the SURTASS LFA source. An additional T-AGOS SURTASS ship (using passive detection only) was made available for the tests to listen for whale vocalizations, and another research vessel was used to collect visual data on individual whales throughout the study and to gather acoustic data, including sound received levels at various distances from the source to confirm transmission loss estimates. Observers using visual and acoustic observation onboard *Cory Chouest* "monitored marine mammals in order to stop broadcasting in case of worrisome behavioral reactions or if any marine mammals were sighted at close enough range that the sound level to which they were exposed might exceed the maximum planned exposure level." [95]

Some 500 hours of passive acoustic data were collected during Phase III of the SRP. Whales exposed to between 115 and 151 dB demonstrated a "variety of responses to [acoustic] playbacks, including

[94] Ibid. (accessed).
[95] Ibid. (accessed).

temporary cessation of song and apparent temporary avoidance response…[although] many whales continued to sing and interact with other whales during playbacks." Researchers estimated that whale distribution and abundance were comparable to data taken in earlier years. Phase III of the Scientific Research Program determined that "roughly half of the whales that were observed visually ceased their song during transmissions, but many of these did so while joining a group of whales (when singers usually stop their songs); all singers who interrupted their songs were observed to resume singing within tens of minutes; analysis of one data set showed that whales increased their song lengths during LFA transmissions, but a second analysis indicated that song length changes were more complicated, and depended on the portion of the song that was overlapped by LFA transmissions; a delayed response to LFA transmissions was observed, in the form of an increase in song length that occurred 1-2 hours after the last transmission; [and that] overall patterns of singer and cow-calf abundance were the same throughout the experiments as they had been during several years of prior study."[96]

In each of the three phases, the effects of low frequency sound on fish and sea turtles were estimated to be lower than anticipated effects on marine mammals in the SRP evaluation. In the case of fish and bony sharks, it was expected that sound might affect either the ears or lateral lines (organs that detect sound or other hydrodynamic stimuli) and lead to either temporary hearing loss or masking through concealment or screening of "biologically relevant signals that could keep fish from pursuing normal activities." But the criterion that was applied during the SRP was that "the risk of physical harm or injury to fish would be no greater than that for marine mammals," and for this to take place, the scientists estimated that individuals would have to be within the mitigation zone (established as the level where 180 dB sound was received). The possibility for this to take place under operational conditions was determined to be of minimal risk because of the few number of LFA systems that would be fielded, (potential) geographic restrictions on their employment, the narrow bandwidth of low frequency sound from the source, the dynamic geometry established between a source moving in two dimensions and fish moving in three dimensions, and the relatively small area that would be ensonified to mitigation zone levels of 180 dB. As for sea turtles, it was again estimated that they would have to be located within the 180 dB mitigation zone for the same criterion

[96] Ibid. (accessed).

of physical harm or injury to transpire as was applied to bony fish and sharks for the LFS SRP, and this was determined unlikely for the same reasons stated above for those other forms of marine life. In addition, since turtles were approximately the same size as small marine mammals, it was considered likely that visual – or perhaps even acoustic – monitoring might reveal their presence in time to prevent their entry into an area where sound levels might prove injurious. With a relatively limited range of habitat, it was further judged that these creatures would not often be subject to LFAS sound where the Navy intended to employ it within certain geographically restricted areas (addressed below).[97]

While far from exhaustive studies on all marine species that might potentially be subjected to and affected by Low Frequency Active Sonar - either in the potential source-receiver geometries tested or with respect to all facets of behavioral impact or physical injury that might be possible - the Low Frequency Sound Scientific Research Program added enormously to the dearth of information that existed on the effects of anthropogenic noise on marine mammals – at *any* frequency. Through the three phases of the LFS SRP, the program was able to test the response of four whales of the mysticetes species to low frequency sound that ranged between 120 and 155 dB. Researchers found it difficult to exceed this level (while remaining below the 160 dB study limit) because of the motion of the whales and limitations on maneuvering source platforms. While early expectations were that whales would respond to sound at levels as low as 120 dB, and "immediately obvious avoidance responses" were expected at sounds greater than 140 dB, the SRP instead found only some short-term behavioral responses across the intensity range to which the whales were exposed. The SRP researchers concluded that, "no significant change in biologically important behavior [was] detected in any of the three phases. Most animals that did respond returned to normal baseline behavior within a few tens of minutes." [98]

With biologically important behavior defined as "related to activities essential to the existence of a species, such as feeding, migrating, breeding, and calving," this was not an exhaustive assessment of impact across any possible range of influence - but such an assessment would be next to impossible given

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[97] *Executive Summary: Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar*, ES23 - ES24.
[98] Ibid., ES15-16.

other factors related to both testing parameters and the near impossibility of identifying a test environment without some other forms of ambient anthropogenic noise. The LFS SRP determined that the received levels experienced by whales in the testing "covered an important part of the RL [received level] range that would be expected during actual SURTASS LFA sonar operations. Thus it follows that the scientific conclusions based on the LFS SRP research data should encompass the majority of SURTASS LFA operational scenarios." Despite this favorable assessment, the Navy decided that it would be "prudent to continue monitoring for potential effects of the SURTASS LFA sonar…to provide additional data to support the resolution of unresolved scientific issues, and respond to anticipated Marine Mammal Protection Act (MMPA) reporting requirements." The conduct of a Long Term Monitoring (LTM) plan "concurrently with the operation of SURTASS LFA sonar will contribute to the body of scientific knowledge on the potential effects of human-made underwater LF sound on marine life."[99]

When the Navy approached the OEIS/EIS process, it was with the intention of employing up to four SURTASS LFA platforms around the world at any given time during routine operations and in times of war. Both Executive Order 12114 and the National Environmental Policy Act required an analysis of a "reasonable range" of alternatives to the Navy's proposal to weigh against the other information provided in the impact statement. Three alternatives were presented in the OEIS/EIS: no action; restricted operation; and unrestricted operation. Under the No Action Alternative, SURTASS LFA would not be developed and employed. Under the restricted operation scenario (Alternative 1), both geographic restrictions and monitoring requirements would be levied on the Navy if it wanted to employ SURTASS LFA. Under Alternative 2, SURTASS LFA would be used without geographic restriction except in areas where the physical environment prevented its use because of operational constraints in shallow water. Additional ASW techniques and technologies (discussed earlier) were considered but not presented as formal Alternatives in the OEIS/EIS. In addition, the Navy studied variations of alternatives that reflected the number of SURTASS LFA ships that might be employed, the areas of the oceans that would "support operation of LFA technology," and various source levels that might be utilized. These variations were eliminated since they "would not fulfill the Navy's primary objective of reliable detection of quieter and

[99] Ibid., ES15 - ES16.

harder-to-find submarines at long range." Consequently in the OEIS/EIS the Navy did not supply data related to "reducing the number of ships equipped with LFA sonar technology to a number less than four, extensive additional geographical restrictions on where LFA sonar technology may be operated, or limiting projector source levels to below 215 dB."[100]

While Alternative 2 levied fewer restrictions on the use of SURTASS LFA, and would be "more operationally flexible and cost-effective for the Navy to implement and operate," it was acknowledged such unfettered use would likely impact both marine mammals and human divers, and that its "implementation would not be consistent with the CNO [Chief of Naval Operations] commitment to the protection of the environment and good stewardship of the seas." Alternative 1 incorporated geographic restrictions that would maintain sound fields below 180 dB within twelve nautical miles of coastlines (the generally accepted limits of territorial seas) and in offshore areas that were considered biologically important; that limited sound fields to less than 145 dB near known commercial or recreational dive sites; and that provided for mitigation strategies to prevent either of these received level criterion from being exceeded. In addition, Alternative 1 specified that visual monitoring by trained personnel would observe for marine mammals and sea turtles in areas of LFAS operations; passive acoustic monitoring would be employed to listen for the presence of marine mammals in areas where LFAS operations were to take place; and active acoustic monitoring using the High Frequency Marine Mammal Monitoring (HF/M3) sonar that the Navy developed in response to public comment during the EIS process would be employed to detect, locate, and track marine mammals (and sea turtles if possible) near and within the mitigation zone where sound levels would exceed 180 dB. With the No Action Alternative a moot point, Alternative 1 – the option that the results of the LFS SRP had determined would provide negligible impacts upon marine mammal populations either from injury or modification of biologically important behavior when conducted with the geographic restrictions and monitoring and mitigation strategies described above - was the choice the Navy supported for employment of SURTASS LFA.[101]

[100] Ibid., ES5 - ES7.
[101] Ibid.

If the Navy's proposed use of Low Frequency Active Sonar was controversial, its efforts to study low frequency effects on marine mammals were not without criticism either. Scientists and members of the public attacked the Navy's scientific strategy, its interpretation of results, and in some instances attempted even to disrupt the experiments as potentially harmful to whales. In a statement the NRDC lawyer who challenged the Navy's environmental stewardship of its low-frequency sonar program, Joel Reynolds, didn't think the Navy went far enough though he was hardly constructive in his criticism, "I simply do not believe that the Navy has addressed the most fundamental problems."[102] Other critics labeled the analysis incomplete and misleading, and that the SRP researchers did not consider enough "about the system's long-term impacts on animal feeding and breeding habits."[103] An abnormally high number of gray whale calves were reported to have stranded in California during the LFAS testing according to one environmental watch group, and protesters swam near the *Cory Chouest* in an attempt to interrupt the LFAS testing near Hawaii.[104] A small number of divers reported ill effects from being in the vicinity of LFAS tests, even though beyond apparently safe ranges. In one instance a diver reported that his lungs vibrated while LFAS was being operationally tested in 1994 off the California coast before the environmental impact statement process began, while in another a diver in Hawaii at the time of the 1998 SRP testing reported post-traumatic stress reactions even though she was swimming five miles from the test vessel. In this latter case, the Navy claimed the diver in question had previously opposed LFAS and was alleging injury to continue her protest.[105]

Some marine biologists considered the Navy's study of humpbacks in the vicinity of the National Humpback Whale Sanctuary to be irresponsible, and one scientist questioned the research design of the LFS SRP altogether, suggesting that studies could have been devised which availed of ambient shipping noise in the same frequencies or correlated incidences of whale strandings with naval operations.[106] At least one whale watch boat captain complained that since the Navy conducted its testing in Hawaii, the

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[102] Quoted in Mark Schrope, "Sonar System Offered Special Dispensation," *Nature* 410, no. 6828 (2001).
[103] David Malakoff, "A Roaring Debate Over Ocean Noise," *Science* 291, no. 5504 (2001).
[104] Stephanie Siegel, "Low-frequency Sonar Raises Whale Advocates Hackles," June 30, 1999 (accessed May 25, 2005); available from http://cnnstudentnews.cnn.com/NATURE/9906/30/sea.noise.part1/index.html.
[105] Siegel, "Marine Mammal Facts Just Drops in the Bucket," (accessed).
[106] Ibid. (accessed).

frequency of humpback whale sightings had decreased near the Big Island and that migration patterns had subsequently shifted his livelihood nearer to Kauai.[107] Nevertheless, the Navy pressed forward with the EIS/OEIS process and published its draft of its efforts for public comment in July 1999, following up a month later with a request for a Letter of Authorization from the National Marine Fisheries Service to harass marine mammals incident to the testing of Low Frequency Active Sonar.[108] The process – and the battle between the Navy and environmental opposition – was far from over, and similar but unrelated events were to change the direction of the dispute significantly in the months ahead.

Et Tu Cetacea?

In March of 1994, the National Research Council's Ocean Studies Board (NRC OSB) published a 76-page report that represented a comprehensive overview of the state of contemporary research on the impact of low-frequency sound on marine mammals. The Office of Naval Research had requested two years earlier that the OSB form of a Committee on Low-Frequency Sound and Marine Mammals to "review the current state of knowledge and ongoing research on the effects of low-frequency (1 to 1,000 hertz (Hz)) sound on marine mammals and to advise the sponsors of the report [ONR] about the effects of low-frequency sound on marine mammals. In addition, the committee was asked to consider the trade-offs between the benefits of underwater sound as a research tool and the possibility of its having harmful effects on marine mammals."[109] At the time, ONR was involved in both LFAS research under the CUARP and as a sponsor of proposed acoustic tomography research after the Heard Island experiment. When the HIFT had encountered last minute regulatory hurdles, it was apparent that this sort of research was no longer "under the radar" of environmental oversight, and ONR requested the National Research Council undertake its study in 1992.[110]

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[107] Stephanie Siegel, "Is Spreading Sonar Smart Science or Overkill?," July 02, 1999 (accessed May 25, 2005); available from http://cnnstudentnews.cnn.com/NATURE/9907/02/sea.noise.part3/index.html.
[108] Eugene H. Buck and Kori Calvert, *Active Military Sonar and Marine Mammals: Events and References* (Washington, D.C.: Congressional Research Service, 2005), RL33133.
[109] National Research Council Committee on Low-Frequency Sound and Marine Mammals, *Low-Frequency Sound and Marine Mammals: Current Knowledge and Research Needs*.
[110] National Research Council Committee to Review Results of ATOCs Marine Mammal Research Program, *Marine Mammals and Low-Frequency Sound: Progress Since 1994* (Washington, D.C.: National Academy Press, 2000), 17.

The OSB committee reported its findings just as the dust-up between the ATOC scientists and environmental opposition ignited. As the size of the volume implied, there was very little to report. "Data on the effects of low-frequency sounds on marine mammals are scarce. Although we do have some knowledge about the behavior and reactions of certain marine mammals in response to sound, as well as about the hearing capabilities of a few species, the data are extremely limited and cannot constitute the basis for informed prediction or evaluation of the effects of intense low-frequency sounds on any marine species." Furthermore, the committee suggested that current regulatory restrictions that applied to harassment of marine mammals – takes under the MMPA – also discouraged research that would benefit their conservation and protection, and recommended that changes in regulatory language providing for waivers would facilitate this process. The committee noted inconsistency between protections for fishing activities that might take marine mammals and non-regulation of sound from commercial shipping industries as opposed to restrictions on scientific research with respect to takes and the use of sound sources to investigate the marine environment.

Not surprisingly, the Ocean Studies Board committee recommended that additional research be conducted on the behavior of marine mammals in their natural habitat; that research be focused on their auditory systems; that investigations be devised into the effects of low-frequency sound on marine mammals as well as their food chain; and that new observational and data gathering techniques be developed for these ends. The committee reported that, as a result of the "dearth of scientific evidence [which] makes it virtually impossible to predict the effects of low-frequency sound on marine mammals" that it was unable to satisfy its charge of balancing the costs and benefits of the use of sound as an underwater research tool with potentially harmful effects on marine mammals. As a statement of the lack of scientific knowledge, the issuance of *Low-Frequency Sound and Marine Mammals: Current Knowledge and Research Needs* was a handbook for those who opposed ATOC on precautionary grounds and left that

program little room to maneuver other than to commit to an expanded Marine Mammal Research Program to begin to address some of these needs.[111]

Six years after the publication of the OSB report on low-frequency sound and marine mammals - after ATOC and its band of civilian researchers had fought (and largely lost) its battles to investigate the world's oceans tomographically, and after LFAS and its Navy sponsors had waged a similar five year contest with opposition groups throughout the development of its OEIS/EIS - the Ocean Studies Board released a follow-on report: *Marine Mammals and Low-Frequency Sound: Progress Since 1994*. The Ocean Studies Board committee charged with this task was focused primarily on the results of the ATOC Marine Mammal Research Program, but also considered what had been learned subsequent to the Navy's Low Frequency Sound Scientific Research Program. The report's findings and recommendations largely reiterated the need for additional research that had been outlined in the first NRC review of the subject, but also recommended specific actions by Congress in its legislative capacity for protecting marine mammals, for the National Oceanic and Atmospheric Administration in its oversight role through the National Marine Fisheries Service, and for the Navy in its efforts to investigate the impact of low frequency sound on marine mammals through its sponsorship of both ATOC and the LFAS programs.[112]

The OSB follow-on report advised Congress to consider "significant disruption of behaviors critical to survival and reproduction" in its definition of harassment of marine mammals, and to "acknowledge the relative significance of different sources of sound in the ocean, insofar as this is known, and provide new means to bring all commercial sources of sound into the MMPA's legal and regulatory framework." NOAA was advised to consider specific activities that were likely to have biologically significant effects as candidates for higher priority of enforcement under the MMPA and the Endangered Species Act and to identify what research might be required to resolve uncertainty related to specific cases together with monitoring requirements as a condition for incidental take authorizations. The Navy was informed that more integrated research was required - rather than case specific research as had been designed to answer

[111] National Research Council Committee on Low-Frequency Sound and Marine Mammals, *Low-Frequency Sound and Marine Mammals: Current Knowledge and Research Needs*.
[112] National Research Council Committee to Review Results of ATOCs Marine Mammal Research Program, *Marine Mammals and Low-Frequency Sound: Progress Since 1994*, 1-8.

somewhat narrow lines of inquiry into the specific ATOC and LFAS scientific research programs. More basic research was recommended into determining the auditory capacity and anatomic structure of hearing organs of marine mammals, and regarding how the animals use sound for communication and other behavioral activities; whether low-frequency sound affects non-auditory physiology or structures of marine mammals; divining the response of deep-diving marine mammals to low-frequency sounds similar to those used either by research scientists or naval sonars; determining sound pressure levels which produce temporary and permanent hearing shifts in marine mammals; and investigating whether low frequency sound affects other creatures in the food chain of marine mammals.[113]

Marine Mammals and Low-Frequency Sound: Progress Since 1994 concluded that even with what had been learned from the efforts of the MMRP and the LFS SRP as well as other research that had taken place since low-frequency sound had become the subject of concern for its potential impact on marine mammals, much remained to be determined, "Our understanding of how marine mammals react to natural and human-made sound is rudimentary. The actions recommended in this report could result in significant advances in knowledge and better regulation of human activities that might be harmful to marine mammals."[114] Involved and as uncertain as this issue was after years of debate and focused research, it was about to become even more so… The acoustic testing and investigations associated with ATOC and with LFAS, and the assessments of the NRC Ocean Studies Board committees that reviewed these and other relevant research efforts on underwater sound, were centered on a rather narrow band of *low frequency* sound. Events that unfolded a few weeks after the release of the second NRC report would raise the level of public outcry over the use of underwater sound and expand the bandwidth by an order of magnitude.

Considering that the utilization of low frequency sound for detecting enemy submarines was wrapped up in an overarching program known as *Project Caesar* during the Cold War, and that both systems that became a matter of intense scrutiny for their effect on marine mammals, ATOC and LFAS, would use IUSS system components in their system designs, it is ironic and perhaps appropriate that the Ides of March provided conceivably the single most significant event in the evolution of the debate over underwater

[113] Ibid.
[114] Ibid., 1-8.

sound. On the morning of 15 March, 2000 a number of Cuvier's beaked whales began washing up on the shores of islands in the Bahamas. One whale washed up literally in front of a research station manned by members of the environmental group Earthwatch and led by whale researcher Ken Balcomb. By the time the group had managed to refloat the whale, other reports were filtering in via the marine mammal stranding network of volunteers throughout the island chain.[115] It was soon learned that a group of U.S. Navy ships had passed offshore conducting a sonar exercise in the Northeast and Northwest Providence Channels very nearly coincident with the strandings which occurred on the beaches of Eleuthera, Great Abaco and Grand Bahamas Islands.

Only two previous mass strandings of beaked whales had been reported in the Bahamas since 1864, each time involving only three or four animals of a single species. The first event took place in February 1968 when four Cuvier's beaked whales beached; the second event occurred only two years prior to the present incident in March of 1998 when three Blainville's beaked whales stranded. Neither of those two events was identified as coincident with naval operations utilizing sonar, but certainly they occurred at a time when U.S. Navy ships were equipped with the ASW detection gear.[116] The significance was not lost on observers - least of all the environmental groups opposed to other Navy-sponsored usage of underwater sound, "If every major environmental issue has a turning point, a moment when its significance becomes too apparent to ignore, that moment for the issue of ocean noise came in Ken Balcomb's backyard in the Bahamas. For it was soon discovered that the strandings there had been caused by military active sonar, a source of intense, mid-frequency sound."[117]

Despite some initial confusion and early reports asserting that LFAS was the culprit, the naval vessels transiting Providence Channel were not operating low frequency active sources – but *had* been utilizing hull mounted sonar systems which operated at higher frequency (three to eight kilohertz, a band considered

[115] Betsy Carpenter, "Sound and Fury," *U.S. News & World Reports*, December 23 2002.
[116] Donald L. Evans and Gordon R. England, *Joint Interim Report: Bahamas Marine Mammal Stranding Event of 15-16 March 2000* (Washington, D.C.: U.S. Department of Commerce / United States Navy, 2001); Michael Jasny, Joel Reynolds, Cara Horowitz, and Andrew Wetzler, *Sounding the Depths II: The Rising Toll of Sonar, Shipping, and Industrial Ocean Noise on Marine Life* (New York: National Resources Defense Council, 2005), 22.
[117] Jasny, Reynolds, Horowitz, and Wetzler, *Sounding the Depths II: The Rising Toll of Sonar, Shipping, and Industrial Ocean Noise on Marine Life*, 1.

medium frequency for naval sonars and that had been in operation on naval ships for decades). But distinctions between sonars for those unfamiliar with their differences could be confusing – and perhaps even irrelevant when emotional issues such as potential harm to marine mammals were at stake. The ongoing OEIS/EIS for LFAS still faced periods of public review before completion; the Navy moved quickly to begin an investigation to separate that issue from what had taken place in the Bahamas. But significant damage had been done; with the beaching of four species of beaked whales on the Ides of March, a new front opened in the battle between environmentalists and the U.S. Navy over the use of sonar, one that shifted frequencies but ratcheted up in intensity.

Bending Perceptions of Marine Mammal Physiology

When the U.S. Navy jointly issued its findings in an interim report with the National Oceanic and Atmospheric Administration, it assumed a large measure of responsibility for the Bahamas stranding incident. The investigation was an exhaustive process that largely worked to exclude all other possible causes before accepting that sonar was responsible for the strandings. All told seventeen cetaceans beached that day: nine Cuvier's beaked whales, three Blainville's beaked whales, two unidentified beaked whales, one spotted dolphin, and two Minke whales. Seven of the animals died; the rest were successfully removed from the beach and returned to the ocean where their fates remain speculative.[118] Under the auspices of a veterinarian designated by the Bahamian government, the animals were necropsied to determine the cause of death. The marine biologists and veterinarians who conducted the investigations into the deaths of the whales could find no external evidence to indicate the whales had somehow been physically injured by vessels or fishing gear, or some other manner of physical blunt trauma such as the primary blast wave from an explosion. Except for the spotted dolphin – which was diseased and whose beaching was concluded to be unrelated to the event which caused the whales to beach – the whales appeared to be reasonably healthy animals. Decomposition set in quickly, and not all of the animals were in the best of condition to

[118] Evans and England, *Joint Interim Report: Bahamas Marine Mammal Stranding Event of 15-16 March 2000*, 1.

necropsy, but some of the heads had been removed and frozen and the lesser preserved remains provided evidence that substantiated findings in the fresher specimens.[119]

Upon completion of more comprehensive examinations, the scientists concluded that there was "strong evidence indicative of acoustic trauma…," and reported, "The most significant findings consisted of bilateral intra-cochlear and unilateral temporal region subarachnoid hemorrhage with blood clots bilaterally in the lateral ventricles in the Blainville's beaked whale and intra-cochlear hemorrhages in the Cuvier's beaked whale." For the layman, the report translated these findings, "In simpler terms, there were deposits of blood within some of the inner ear chambers, and in at least one animal the blood trail can be traced to a hemorrhage in a discrete region of a fluid space surrounding the temporal regions and within a ventricle of the brain. Some type of auditory structural damage findings are present in all four beaked whales examined (all showed bloody effusions or hemorrhage near and around the ears)." These findings suggested that the animals' ears "were structurally intact and [that] the animals were alive at the time of injury." This then made it most likely that the animals had suffered an acoustic trauma.[120] What remained a matter of speculation – however circumstantial the evidence appeared by the presence of the Navy ships at the time of the strandings – was what type of acoustic trauma might have triggered this event.

Despite the necropsy findings that "some acoustic or pressure event occurred that had characteristics especially significant or traumatic for these beaked whale species…," there was still factors that remained inconclusive – what else besides the sonar exercise might have caused the effects? For this researchers turned to acoustic records gathered by two NOAA recording stations near enough to detect acoustic or pressure events in the region. The first and closest of these stations was in the Tongue of the Ocean – a rather descriptive analogy of the shape of this passage near Andros Island when one observes its bathymetric contours on a map – which recorded lower frequency signals between forty-five hertz and a "few hundred hertz" every eleven seconds. While not an absolute manner to record possible explosions, it was considered a reliable measure for other acoustic/pressure events such as landslides, underwater earthquakes or volcanic activity. A second set of hydrophones on the Mid-Atlantic ridge recorded signals

[119] Ibid., 12-13.
[120] Ibid., 12 - 13.

continuously between one and fifty hertz and were "moored in the oceanic sound channel, allowing long-range detection of low-frequency events." Between these two detection sources, there appeared to be no other acoustic or pressure events aside from the sonar exercises that might have caused the strandings, "Although numerous earthquakes were detected from around the Atlantic, and seismic airgun sounds were detected from the Nova Scotia region, there was no indication of any unusual sources of low-frequency acoustic energy emanating from the Bahamas region during the March 13-16 time period. This result eliminates the possibility that tissue damage observed in beaked whales resulted from a distant explosion or geological event."[121]

Conducting the inquiry for the U.S. Navy, the Office of Naval Research next turned to acousticians to model the behavior of the sound that emanated from the naval sonars during the ships' passage through the Providence Channels. From an expendable bathythermograph profile taken at the time and from historical climatological data which closely matched the XBT sounding it was determined that a relatively well mixed upper layer of the ocean created what is known as a surface duct. Essentially this means that the upper surface waters exhibited uniform thermal characteristics as a result of mixing and that the primary effect on propagation of sound was the effect of pressure with increasing depth. This caused the sonar sound waves to remain primarily in this upper layer of water and not penetrate to the ocean floor where a relatively silty bottom would have further attenuated the signal beyond the additional spreading and absorption losses that would have occurred outside of the duct.[122] Any whales swimming in the vicinity of the vessels that remained in this upper surface region and did not dive beneath the mixed layer would have been exposed to relatively high levels of received sound.

The geography of the area and the bathymetry of the channel constrained options for any animals in the vicinity to evade the ships or the sounds emanating from them; whales swimming in the Providence Channel would have effectively been herded ahead of the vessels…or been forced to beach if they attempted to swim laterally from them. Ironically the Navy was operating in the Bahamas rather than in a region it normally utilized and where it had conducted similar exercises for many years beforehand.

[121] Ibid., 21.
[122] Ibid., 22-27.

Environmental opposition to the Navy's use of the Vieques range in Puerto Rico had made the exercises impossible at that time of a highly publicized controversy that eventually led to the closing of the Vieques range and the almost complete withdrawal of the U.S. Navy from a long-term operating base at Roosevelt Roads.[123] The scientific analysis of the exercise conducted in the Providence Channel after the March 2000 beaching events indicated that the selection of this site may have contributed to the strandings because of relatively unique oceanographic and geographic conditions that the Navy had not experienced in the numerous earlier operations it had conducted near Vieques.

A number of sound sources were considered in the acoustic modeling efforts, including "noise from harbor and shoreline construction, lightning, gunnery exercise, explosive noise such as (illegal) fishing activities, vessel traffic, oceanographic research, and naval exercises involving the use of standard hull-mounted mid-frequency range tactical sonars. The search identified tactical midrange sonars as the most plausible source of acoustic energy that met the necessary criteria of location, timing, and sound amplitude that could have reasonably accounted for the widely separated multiple strandings."[124] Consequently, the modeling team used a number of acoustic propagation algorithms to estimate the shape of the sound patterns and propagation paths, the areal extent and intensity of ensonification, and the relative timing of sonar emissions with strandings. The sonars in question were on two classes of naval ships, FFG7 *Oliver Hazard Perry*-class frigates and DDG51 *Arleigh Burke*-class destroyers. The frigates utilized AN/SQS-56 sonars which operated between 6.8 and 8.2 khz at source levels as high as 223 dB, and the AN/SQS-53C sonars on the destroyers operated between 2.6 and 3.3 khz at a nominal source level of 235 dB but were reported to have operated at higher (classified) output levels for at least some portion of the channel passage. The different frequency ranges and sonar operating parameters provided alternative benefits and limitations in littoral environment; pairing units with the SQS-56 and the SQS-53C optimized the capabilities of the two sonars in conducting the ASW exercise in the Providence Channels.[125]

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[123] Ibid., 22.
[124] Ibid., v, 22.
[125] Ibid., 22-25.

Model results indicated that the AN/SQS-56 emitted sounds that might have been as high as 180 dB at a range of 300 meters from the vessel, but because of the beam characteristics were unlikely to have penetrated the lower layer of the duct with this intensity of noise. Operating at 235 dB, the AN/SQS-53C sonars were estimated to have projected sound at 180 dB intensity as far as 1,000 meters from their hydrophones which was also not believed to have penetrated the lower limit of the duct at this intensity, but with the beam-forming characteristics of this sonar it was estimated that that sound as high as 160 dB could have propagated within the duct to a range of 34 kilometers and below the duct as far as 10 kilometers from the source. When the 53 "Charlie" operated at the higher classified source levels, sound pressure levels as high as 180 dB were estimated to exist as far as 5 kilometers from the source within the duct and up to 1.4 kilometers away below the 200 meter deep surface layer. The report stressed that the use of 180 dB and 160 dB were just arbitrary levels analyzed to provide relative comparisons, and were not meant to indicate any biologically significant effects associated with these two levels of sound intensity. While it was obvious that the higher source level utilized by the AN/SQS-53C by one of the ships in the exercise might have provided a breakpoint that caused the whales to react – where maybe they would not have otherwise, providing for some of the uniqueness of this event – the researchers determined that the spatial and temporal patterns of strandings indicated that this higher source intensity associated with a single vessel was not likely the sole reason for the response of the whales across the span of the entire event.[126]

The conclusions reported by the joint NOAA-Navy investigation were of consequence for the future use of sonars in the presence of marine mammals – or other marine species for that matter, and the methodical investigation had worked its way towards a conclusion that the use of mid-frequency sonar was the only reasonable cause. From the post-mortem biological studies and concurrent environmental studies of ambient conditions at the time of the incident, a number of possible mechanisms that might have served to cause the whales to strand had been ruled out: "biotoxins (red tide), malnutrition, chronic disease, inflammatory disease, meteorological events, earthquakes, volcanism, landslides, neoplasms (cancer), fisheries injury, blunt trauma from ship strike, nearby explosion, distant explosion, birth trauma, LWAD (a U.S. Navy exercise using sonobuoys), and Low Frequency Active sonar (SURTASS LFA)." Three other

[126] Ibid., 28-29.

potential causes for strandings and for the types of injuries these animals had received were investigated and also set aside as possible explanations for the strandings: acute chemical contamination was discounted for lack of any evidence of a spill; "spontaneous subarachnoid hemorrhage" which can occur in individual marine mammals was deemed an unlikely coincidental event for such a large group; and lastly a bleeding disorder known as a diathetic disease was excluded for while possible in individual animals was unlikely to be found in so many cetaceans involved in related but physically separated strandings.[127]

The proximate cause of death for the whales in the Bahamas incident was not directly attributable to the potential acoustic injuries noted in the necropsies; rather the animals died from standard beaching effects observed in numerous other strandings: overheating, cardiovascular collapse, and physiological shock. By no means did this absolve any responsibility for the event; if someone were pushed in front of a bus, surely the impact of the vehicle would be the cause of the injuries, but the push would be the ultimate reason for the accident. Many questions and factors remained that might have contributed, including the fact that these whales were social animals known to mass strand; even if mass stranding events were infrequent, there remained the possibility of a problem in a dominant animal that might cause its mates to strand along with it. While possible, in the Bahamas stranding event this causal factor was refuted by the presence of similar intercranial injuries among a number of the animals.[128] When other causes had been investigated and discounted, what remained was the presence of identifiable acoustic pressure traumas in the necropsied animals. Although "…technically the analyses to date cannot differentiate between far-field blast effects and acoustic induced injury from single or multiple sources," some significant event of this nature *had* nevertheless occurred Once the study of the seafloor hydrophone data revealed no other possible acoustic sources, the search was up, "Therefore, by deduction, it is reasonable to assume the injuries were acoustically induced [by naval sonars]."[129]

The Joint Interim Report on the Bahamas Marine Mammal Stranding issued findings that did little to help the Navy's case for using underwater sound in any fashion, " Based on the way in which the

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[127] Ibid., 46.
[128] Ibid.
[129] Ibid., 15.

strandings coincided with ongoing naval activity involving tactical mid-range frequency sonar use in terms of both time and geography, the nature of the physiological effects experienced by the dead animals, and the absence of any other acoustic sources, the investigation team concludes that tactical mid-range frequency sonars aboard U.S. Navy ships that were in use during the sonar exercise in question were the most plausible source of this acoustic or impulse trauma." The report acknowledged that specific and unique factors were at play, "This sound source was active in a complex environment that included the presence of a surface duct, unusual underwater bathymetry, intensive active use of multiple sonar units over an extended period of time, a constricted channel with limited egress, and the presence of beaked whales that appear to be sensitive to the frequencies produced by these sonars. The investigation team concludes that the cause of this stranding event was the confluence of the Navy tactical mid-range frequency sonar and the contributory factors note above acting together." [130]

The joint NOAA-Navy report indicated that "contributory" factors might vary in relevance, and that further research was necessary to identify other "problematic combinations so they can be avoided." What is more, since the "actual mechanisms by which these sonar sounds could have caused animals to strand, or their tissues to be damaged, have not been revealed," more research in these areas was necessary and by the time the report was issued was already underway. "This research, along with other research on the impacts of sonar sounds on marine mammals, increased knowledge of marine mammal densities, increased knowledge of causes of beaked whale strandings, increased knowledge of beaked whale anatomy, physiology and medicine, and further research on sonar propagation, will provide valuable information for determining which combinations of factors are most likely to cause another mass stranding event." While the report proved an open indictment of the use of mid-range frequency sonars at least under the confluence of conditions that led to Bahamas strandings, it's methodical approach and exhaustive findings also allowed the Navy to publish another conclusion important to its long-term goals: "SURTASS LFA, another Navy sonar, had no involvement in this event."[131]

[130] Ibid., 47.
[131] Ibid.

Occurring as it did during the Navy's efforts to produce an OEIS/EIS for its planned deployment of Low-Frequency Active Sonar, the Bahamas stranding event was a blow to theories that intense underwater sounds would not demonstrate injurious or biologically significant impacts upon marine mammals. But the Navy had weathered this event well, preparing a comprehensive joint investigation that involved numerous leading scientists and the conclusions of which laid the blame at the Navy's own doorstep…and for which it then accepted responsibility. The Bahamas event was clearly separate from the low-frequency investigations the Navy wished to pursue with LFAS, and with scientific evidence to back it up, the Navy was in a strong position to fight back when opponents deliberately or through their own misinformation attempted to conflate the two technologies and their demonstrated impacts. This does not mean that the Navy planned or ever intended to give ground with its mid-frequency range sonars, devices it had used for decades and that were in use by many nations around the world. Rather the Navy pledged to keep marine mammal protection first at hand when exercises were to be conducted and committed to a series of mitigation efforts to ensure that mammals were not injured in the future.[132]

Accordingly the Navy carefully stepped through the environmental impact statement process for the development of LFAS. In August 1999 the Navy had submitted an application for a Letter of Authorization from the National Marine Fisheries Service for the incidental harassment of marine mammals incident to the development and operation of its SURTASS LFA system. After the appropriate periods for public comment and numerous public outreach events, the Navy issued its Final Overseas Environmental Impact Satement/Environmental Impact Statement (FOEIS/EIS) in January 2001, and two months later the NMFS proposed a rule in the *Federal Register* authorizing the Navy to harass marine mammals incident to its development of LFAS. The NMFS concurred with the Navy's OEIS/EIS that "the incidental taking of marine mammals resulting from SURTASS LFA sonar operations would result in only small numbers…of marine mammals being taken, have no more than a negligible impact on the affected marine mammal stocks or habitats and not have an unmitigable adverse impact on the Arctic subsistence use of marine mammals." The NMFS conclusions were "supported by the proposed mitigation measures that would be implemented for all SURTASS LFA sonar operations and the proposed LTM [long-term

[132] Ibid., vi.

monitoring] program." Further, the NMFS judged that the Navy proposal was likely to have limited impact as a result of "geographic operation restrictions, mitigation measures to prevent injury to any marine mammals, monitoring and reporting and supplemental research that will result in increased knowledge of marine mammal species, and the potential impacts of LF sound on these species." In its assessment the NMFS considered that takes would be negligible as a result of "(1) The small number of SURTASS LFA sonar systems that will be operating worldwide; (2) the vessel must be underway while transmitting (in order to keep the receiver array deployed); (3) the low duty cycle and short mission periods; and (4) the possibility of a marine mammal being within the 180-dB sound field during sonar transmissions is unlikely."[133]

The NMFS announcement opened a period of public comment that allowed for letters from concerned or interested parties and a period of public outreach meetings to address the issue related to low-frequency sound and SURTASS LFA. The normal 45-day period was extended to 73 days and lasted through May 31, 2001. During this time hearings were held in Los Angeles, Honolulu, and Washington, D.C., and NMFS received over 10,000 letters which opposed the Navy's request. To digest and address the points made through these public comments, NMFS took a year before issuing a statement of Biological Opinion in May 2002, and subsequently publishing its intent to issue the take authorizations to the Navy coincident with its use of SURTASS LFA. A number of points were made in this final rule that indicated that NMFS considered the Navy's research and proposed operating parameters into account in its decision, as well as the voluminous public comments that had expressed opposition to the proposal.

While the Bahamas stranding report's use of the 180 dB isopleth as a measure of sound intensity had not been indicative of biologically significant exposure, the NMFS rule utilized that figure after "the best available science to date indicates that if marine animals could be excluded from an area having a SPL [sound pressure level] of 180 dB or higher, they would not likely be injured." Consequently the authorization rule incorporated "the Navy's commitment that the 180 dB re 1 µPa SPL isopleth would

[133] National Oceanic and Atmospheric Administration National Marine Fisheries Service, "Taking Marine Mammals Incidental to Navy Operations of Surveillance Towed Array Sensor System Low Frequency Active Sonar," *Federal Register* 66, no. 53 (2001).

remain at least 12 nm [nautical miles] from all coastlines, including islands. This measure ensures that coastal stocks of marine mammals and sea turtles will be relatively unaffected by LFA sonar due to high attenuation of sound in shoaling water. In addition, the Navy has established a safety zone for human divers at 145 dB around all known human commercial and recreational diving sites. Although this geographic restriction is intended to protect human divers, its implementation will also reduce the LF sound levels received by marine mammals, sea turtles and fish that are located in the vicinity of known dive sites."[134]

It was estimated that the 180 dB sound pressure level isopleth would not, under the operating characteristics of the LFA source, extend more than one kilometer from the hydrophone array. Consequently a one kilometer safety zone was established within which detection of any marine mammal would require the Navy to terminate transmissions. The NMFS considered this to be a conservative zone of protection, especially since some marine mammals were known to vocalize at higher sound pressure levels. Outside this safety zone, detection of marine mammals would be achieved through three methods in order to cease transmissions before any animals entered this potentially injurious region: visual monitoring by trained observers, passive monitoring using the SURTASS hydrophones, and active high frequency sonar monitoring utilizing the specially developed High Frequency Marine Mammal Monitoring (HF/M3) sonar affixed to the SURTASS array. A one kilometer buffer zone around the safety zone was established in which these combined mammal surveillance techniques would monitor for the presence of marine mammals.[135]

After the 2000 Bahamas stranding event had determined that (relatively) higher frequencies did have apparently injurious characteristics for marine mammals, an upper limit of 330 Hertz – the technologically feasible limit for the LFAS source – was established instead of the 500 Hertz that the Navy had requested in its OEIS/EIS. This limit was established to ensure that resonance such as the type that apparently injured

[134] National Marine Fisheries Service, "Final Determination and Rulemaking on the Harrassment of Marine Mammals Incident to Navy Operations of Surveillance Towed Array Sensor System low frequency Active (SURTASS LFA) Sonar: Executive Summary," 2002 (accessed January 01, 2005); available from http://www.nmfs.noaa.gov/prot_res/readingrm/MMSURTASS/LFAexecsummary.pdf.
[135] Ibid. (accessed).

the beaked whales in Providence Channel would not be induced by LFAS operations. Scientific evidence presented in Congressional testimony had indicated that above 300 Hertz virtually all marine mammal species might be affected. With the sound attenuation effects of the safety and buffer zones, and an upper limit on operating frequency, it was expected that animals would not be exposed to potentially injurious sound pressure levels at frequencies that might cause the resonance-induced tissue damage seen in the Bahamas incident. In addition to these dynamic protection zones based upon a moving source, and aside from the aforementioned coastal geographic restrictions, additional limitations were placed upon the operation of LFAS near Offshore Biologically Important Areas (OBIAs).[136]

Within OBIAs sound pressure levels could not exceed 180 dB, even though it was considered unlikely that the Navy would operate its sonar near these regions as a result of the likelihood of marine mammal presence associated with the OBIA. Nevertheless these regions – which included "the waters of the East Coast of the United States and Canada from Florida to Newfoundland out to the 200-m [meter] isobath to protect right whales, the subarctic convergence zone during the austral summer, the Costa Rica dome in the Pacific Ocean, and Penguin Bank off the Island of Kauai, Hawaii, inside the Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS)" – were afforded specific protections under the NMFS rule. Similar protections were afforded to other National Marine Sanctuaries that extended beyond 12 nautical miles from coastlines, including Monterey Bay, the Gulf of the Farallones, and Cordell Bank in addition to the HIHWNMS.[137] Anticipating widespread public interest about its rule authorizing harassment of marine mammals incident to the Navy's SURTASS LFA program, the National Marine Fisheries Service published an extensive series of Questions and Answers for the public that covered both the rulemaking process, as well as the operation of low frequency active sonar and its effects on marine mammals. Dispelling many misconceptions, and justifying its decision with numerous comparisons to other sound sources in the seas, the Q&A series makes one concise statement that might easily be overlooked among the pages of topics: "NOAA fisheries has never required such extensive mitigation on

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[136] Ibid. (accessed).
[137] Ibid. (accessed).

any other acoustic project. Furthermore, SURTASS LFA uses three forms of mitigation (visual sighting, passive acoustic, and HFM3) whereas others use only visual sighting."[138]

The Navy acted quickly upon the NMFS ruling, registering its decision to deploy "two SURTASS LFA sonar systems with certain geographical restrictions and monitoring mitigation designed to reduce potential adverse effects on the marine environment…[which] implements the preferred alternative, Alternative 1, identified in the Final OEIS/EIS for SURTASS LFA Sonar."[139] The Navy had earlier stated its requirement to counter quieter adversary submarines in the post-Cold War world in its OEIS/EIS. By the time of the NMFS ruling and the Navy's decision to deploy LFAS, it was the post-9/11 world. On its website, the Navy readdressed its requirement for this sonar technology under the heading "Why the United States Needs SURTASS LFA." The subsequent explanatory wording may not have been deliberately connected to this particularly emotional issue, but then again it may have deliberately intended to link this naval requirement to emergent security concerns: "Anti-Submarine warfare (ASW) is an essential part of the Navy's defense mission. Submarines are the ultimate stealth weapons, and the Navy must be able to detect them at long distances, before they pose a danger to our surface ships. Currently there are 224 submarines operated by non-allied nations, and the submarines prowling the world's oceans today are much quieter and more deadly than ever before. *An undetected enemy submarine is an underwater terrorist, threatening any surface ship or coastline within its range*.[emphasis added]"[140]

The same sense of renewed mission is evident in the Navy's Record of Decision: "Pursuant to 10 U.S.C. 5062, the Navy is required to be trained and equipped for prompt and sustained combat incident to operations at sea. To fulfill this mandate, the Navy provides credible, combat-ready naval forces capable of sailing anywhere, anytime as powerful representatives of American sovereignty. Fleet readiness is the foundation of the Navy's war fighting capability, and there is a direct link between fleet readiness and training. For the Navy, fleet readiness means essential, realistic training opportunities, in both open-ocean

138 National Marine Fisheries Service, "Questions and Answers about Ocean Noise," 2002 (accessed January 01, 2005); available from http://www.nmfs.noaa.gov/prot_res/readingrm/MMSURTASS/LFAoceannoise.pdf.
139 Department of the Navy, "Record of Decision for Surveillance Towed Array Sonar System Low Frequency Active (SURTASS LFA) Sonar," *Federal Register* 67, no. 141 (2002): 48145.
140 United States Navy, "SURTASS LFA," (accessed).

and littoral environments." The justification continues, "The Navy is facing existing and emerging threats from foreign naval forces. For example, several non-allied nations are fielding new, quiet submarines. New anti-ship, submarine-launched cruise missiles are also being introduced. When quiet submarines and anti-ship cruise missiles are combined, they pose a formidable threat to our sailors and Marines, who are called upon to project power from the sea and maintain open sea lanes." The technology was critical, but operational testing and exercise was equally important, "In order to successfully locate and defend against these threats, our sailors must train realistically with both active and passive sonar. In executing antisubmarine (ASW) missions, sonar is the key to survival for our ships and sailors. The employment of SURTASS LFA will enable the Navy to meet the clearly defined, real-world national security need for improved ASW capability by allowing Navy Fleet units to reliably detect quieter and harder-to-find foreign submarines underwater at long range, thus providing adequate time to react to and defend against the threat, while remaining a safe distance beyond a submarine's effective weapons range."[141] At a time when U.S. naval forces were delivering combat power in response to the terrorist attacks of 9/11, national security justifications resonated much more than in the amorphous post-Cold War period when the United States military was without a definitive adversary around which to rally political and public support.

The First Salvos of Lawfare

Environmental opposition to the SURTASS LFA did not evaporate, however, even in the heightened period of security awareness and more widespread public support that existed after the September 2001 attacks on the United States. The Ocean Conservancy opposed the NMFS rule on the grounds that the NOAA organization "lacks the scientific knowledge to issue such a permit and cannot demonstrate that LFA sonar technology will have a negligible impact on marine mammal populations." The National Resources Defense Council also opposed the issuance of a go-ahead to the Navy on general principles related to the use of underwater sound by marine mammals which use "their exquisitely sensitive hearing to follow migratory routes, locate one another over great distances, find food and care for their young. Noise

[141] Department of the Navy, "Record of Decision for Surveillance Towed Array Sonar System Low Frequency Active (SURTASS LFA) Sonar."

that undermines their ability to hear can threaten their ability to function and survive."[142] Only a few weeks after the Navy issued its Record of Decision, a group of environmental organizations led by the NRDC banded together to sue the U.S. Navy and the National Marine Fisheries Service over the deployment of the sonar. Announcing the lawsuit, one of the NRDC lawyers Joel Reynolds said, "One of the truly disturbing aspects of this system is its unprecedented power and geographic scope. If the Navy deploys LFA, tens of thousands of square miles of ocean habitat would be saturated with extremely loud and dangerous sound. The Navy has illegally been given a blank check to deploy LFA in 75 percent of the world's oceans."[143]

Aligning with the NRDC and labeling the decision "a license to kill," Jean-Michel Cousteau of the Ocean Futures Society alleged that, "Despite the public and scientific outcry, the National Marine Fisheries Service, under whatever pressure, has licensed the U.S. Navy to basically break the law." The Navy responded that it was a disappointment that these groups "refuse to accept scientific peer-reviewed findings and instead rely on misinformation and unrelated facts to try and prevent the use of this system." NMFS was not silent either, "We consider (the impact) to be negligible. If we find out differently, we can halt the authorization." The Director of the Woods Hole Research Center disagreed, "The organisms we're talking about have in their heads a system for seeing with sound that's just as good as our system for seeing with light. If we flood the oceans with sound that has enormous energy, we're killing them." A marine mammal specialist with the Humane Society was similarly concerned that the Navy system could deafen the creatures or induce tissue resonance that might "tear body tissue much like an opera singer can shatter glass." The League for Coastal Protection and the Cetacean Society joined the Humane Society, the Ocean Futures Society, and NRDC in filing the lawsuit.[144]

Despite the litigation, the National Marine Fisheries Service issued the Navy a Letter of Authorization to conduct low frequency operations between August 16, 2002 and August 15, 2003. The LOA authorized

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[142] Quoted in Environment News Service, "Navy OKd for Sonar Blasts that Could Harm Whales," July 17, 2002 (accessed February 20, 2006); available from http://www.ens-newswire.com/ens/jul2002/2002-07-17-02.asp.
[143] Quoted in Cetacean Society International, "Sonar, Seismic Surveys, Lawsuits and Voters Make Loud Noises," *Whales Alive!*, October, 2002 (accessed March 10, 2005); available from http://csiwhalesalive.org/csi02404.html.
[144] Quoted in Associated Press, "Navy Sued Over Sub-Detecting Sonar," August 08, 2002 (accessed August 23, 2005); available from http://www.cbsnews.com/stories/2002/08/08/tech/main518009.shtml.

the Navy to operate its LFA system from *R/V Cory Chouest* according to the parameters it had laid out in its rule-making decision in a number of areas of the Pacific Ocean including the Archipelagic Deep Oceans Province, the North Pacific Tropical Gyre East and West Provinces within the Pacific Tradewind Biome and the Kuroshio Current Province, and the Pacific Subarctic Gyres (West) Province in the Pacific Westerly Winds Biome. Limited to operations between 100 and 330 Hertz and at a maximum source level of 215 dB, 423 transmit hours comprising six or more missions were allowed under mitigation procedures promulgated in the NMFS rule-making announcement that included visual, passive acoustic and active acoustic monitoring. Additional geographic restrictions pertaining to the use of SURTASS LFA outside of twelve nautical miles from coastlines, within offshore biologically important areas and near national marine sanctuaries were imposed. Quarterly classified reports were required detailing the areas where LFA SURTASS was used, the operating parameters that were employed, and significant observations of marine mammal impacts from this use. Unclassified annual reports would summarize the quarterly reports in more general terms and address the effectiveness of mitigation efforts, as well as any long-term effects and perceived cumulative impacts from SURTASS LFA operations.[145]

Before the Navy could move forward under this authorization, however, in October 2002 a federal judge temporarily halted the Navy's deployment of SURTASS LFA, agreeing with the plaintiffs led by NRDC that the sound might harm whales and other marine mammals. The judge ordered the Navy to consult with the environmental groups who opposed its use of the sonar system to find ways that balanced the interests of both sides of the argument.[146] Although not nearly as widely known or reported, the Navy was not the only institution under fire for utilizing high intensity sound in this timeframe; in a separate court case the Center for Biological Diversity opposed a National Science Foundation research project to map the seafloor utilizing air guns in the Gulf of California. The project was alleged to have caused the beachings of two whales found dead on the coast nearby. Researchers from the Lamont-Doherty Earth Observatory of Columbia University that were conducting the research had taken "additional steps to limit the impact of the work, including reducing the intensity of the sound signals, restricting the research area, limiting

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[145] National Marine Fisheries Service, "Letter of Authorization," August 16, 2002 (accessed January 01, 2005); available from http://www.nmfs.noaa.gov/prot_res/readingrm/MMSURTASS/LFA_LOA_02.pdf.
[146] "Court-Ordered Silence," *Science* 298, no. 5596 (2002).

operations to daylight, and enlisting Mexican researchers to monitor marine mammal activity." Even so, the work was halted by court order.[147]

In mid-November the judge in the SURTASS LFA case vacated the injunction she had issued in October after the Navy and the environmental opposition groups agreed to a more limited deployment of the systems, although the case remained open and the judge indicated she would rule on the matter the following summer. To move forward, the Navy had made a number of concessions. Instead of operating over 14 million miles of the North Pacific according to the authorization it had received from the National Marine Fisheries Service, the Navy agreed to operate in a more restricted region of approximately one million square miles near the Marianas Islands in areas deemed "less productive" biologically than other areas of the originally proposed range. The environmentalists accepted the agreement when they determined that the judge was unlikely to order a ban over near as large an area, and vowed to seek permanent revocation of the Navy's permit. Under the terms of the agreement, the Navy was allowed to begin immediate testing of the SURTASS LFA system in areas that avoided whale migration routes, feeding areas and breeding grounds.[148]

With authorization in hand, the U.S. Navy prepared for the reintroduction of LFAS into the Fleet after almost five years since its last use during the 1997-1998 Low Frequency Sound Scientific Research Program. But controversy over the use of sonar and its impacts upon marine mammals was far from over, although attention soon reverted from low-frequency back to the mid-range frequencies that had been implicated in the Bahamas strandings. That event had raised awareness over the connection between naval sonars already in use and impacts upon marine mammals, as opposed to the theoretical impacts threatened by yet-operational lower frequency systems. Only a matter of months passed before the issue was once again front page news in the United States. On its way to the Canadian Forces Maritime Experimental Test Range in May 2003, the destroyer *USS Shoup* operated its SQS-53C sonar to conduct a "swept channel"

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[147] Associated Press, "Judge: Stop Whale-Harming Research," October 28, 2002 (accessed August 23, 2005); available from http://www.cbsnews.com/stories/2002/10/16/tech/main525869.shtml.
[148] Environment News Service, "Controversial Navy Sonar Cleared For Limited Testing," November 18, 2002 (accessed February 20, 2006); available from http://www.ens-newswire.com/ens/nov2002/2002-11-18-06.asp.

exercise in the Haro Strait north of Puget Sound in the State of Washington. When the destroyer approached the range in Canadian waters, numerous complaints were registered with the Canadian coast guard from boaters and whale watchers “about bursts of underwater sound thrumming through boat hulls.”[149]

When the destroyer was notified that it might be disturbing marine life, *Shoup* secured sonar operations, but the incident had only just begun. Witnesses to the vessel’s passage through the Haro Strait reported that “killer whales and other marine mammals frantically fled from the area” while the sonar was in operation. Over a span of two weeks more than a dozen dead porpoises were gathered from beaches or found floating in the area. The Governor of Washington wrote to the Acting Secretary of the Navy to express his concern over a potential connection between the porpoise deaths, and to ask what steps the Navy had implemented in the wake of the Bahamas incident to avert further injury to marine mammals. He noted that Washington’s orcas had protected status and expressed concern that Navy operations might disturb these “local icons.”[150] Scientists from around the country were solicited to study the dead porpoises which had been frozen to preserve them until an expert team could be assembled for the necropsies. Meanwhile, National Marine Fisheries Service scientists cautioned that springtime strandings of harbor porpoises were not uncommon and that, “At this point, there is no evidence any of these deaths were connected to the Shoup except for coincidence in time.”[151]

Speculation over the deaths of the porpoises and whether *Shoup*’s sonar was to blame swirled for months while the scientists conducted their studies, the results of which were not released until February 2004. At that time, the scientists concluded that they “found no evidence that sound waves were a factor.” Two of the animals died from blunt force traumas – perhaps caused by collisions with vessels – and illness was determined as the cause of three others; no cause of death was determined for the remaining six animals studied, although scientists noted that decomposition made it difficult to determine causes of death

[149] Christopher Munsey, "Porpoise Deaths Raise Questions about Sonar, Future Use of Range," *Navy Times*, July 07, 2003.
[150] Associated Press, "Governor Questions Navy about Sonar Disruption of Whales," June 10, 2003 (accessed June 10, 2003); available from http://www.navytimes.com/1928254.php.
[151] Quoted in Associated Press, "Did Navy Tests Kill Porpoises?," July 23, 2003 (accessed August 23, 2005); available from http://www.cbsnews.com/stories/2004/02/10/tech/main599215.shtml.

related to soft tissues.[152] The Navy's internal study was released a day after the NMFS-sponsored investigation, and concluded that *Shoup*'s sonar had not harmed the porpoises nor had it disturbed a pod of killer whales – a subject not addressed by the initial NMFS report, but that remained under investigation by that organization. The Navy study noted that seven of the porpoises had been found prior to the time *Shoup* had been underway and eight were found weeks after the exercise; only one had been found in the vicinity of the ship's passage. Nevertheless, the Navy admiral in charge of the service's Northwest Region stressed the Navy's interest and concern for the issue, "We take every death of a marine mammal possibly associated with the use of sonar as important. We comply with the law."[153]

The Navy's investigation about allegations that it had disturbed orcas in the Haro Strait stemmed from compliance with the Marine Mammal Protection Act and the possibility that it had inadvertently "taken" marine mammals through an activity not permitted for such action. The Navy requested a panel of marine mammal experts to review videotapes of the incident and conducted acoustic studies to determine whether the orcas might have been exposed to potentially harmful sounds. The experts did not assess from their review of the videos that any evidence of disturbance was present as a result of the passage of the navy destroyer – though interestingly enough in a picture from the video published in the press whale watching boats can be seen very close to the pod of whales with the naval vessel steaming in the background. Others disagreed with the Navy's findings; a member of the Orca Conservancy voiced his organization's displeasure, "It's important to recognize that while the findings of the NMFS study were inconclusive, the Navy chose to interpret that as if they were not to blame."[154]

A year later when the National Marine Fisheries Service released its report regarding the possibility that the Navy had harassed the orcas in the Haro Strait, its conclusions did not parallel the Navy's. The NMFS study concluded that while the Navy sonar was likely loud enough to cause the whales to avoid it, it was not loud enough to injure the animals or cause temporary or permanent hearing damage. For its part, the

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[152] Associated Press, "Team Can't Link Porpoise Deaths, Sonar," February 10, 2004 (accessed February 11, 2004); available from http://www.latimes.com/archives.
[153] Christopher Munsey, "Reports Can't Link Sonar, Porpoise Deaths," *Navy Times*, February 23 2004.
[154] Associated Press, "Report: Destroyer's Sonar Affected Whales," March 17, 2005 (accessed March 17, 2005); available from http://www.navytimes.com/727914.php.

Navy acknowledged that *Shoup*'s sonar was likely the "dominant noise event" in the Haro Straits that day, but maintained that the "biological significance" of the event was minimal. Ken Balcomb, a researcher from the Center for Whale Research in Friday Harbor, Washington – the same Ken Balcomb who witnessed the Bahamas stranding event years earlier – argued that actual hearing loss was almost besides the point for a species dependent upon sound for many aspects of its existence, "They are trying to get away, and they are stranding and dying. It is irrelevant whether they had hearing loss if they are dead."[155] The State of Washington did not stand by idly as the National Marine Fisheries Service, the Navy, and concerned individuals debated the impact upon what the Governor had described as local "icons." In April 2004, the Washington Fish and Wildlife Commission voted to add the animals to the state's endangered species list and requested federal officials to review their status under the federal Endangered Species Act, in order to "require federal agencies to take actions to protect habitat for killer whales."[156]

Two incidents had very publicly involved the United States Navy in embarrassing public relations cases with respect to the use of mid-frequency sonar and marine mammals; but these were not the only cases implicating the use of naval sonar in incidents that injured or killed marine mammals. Other cases added to the evidence that at least some frequencies of sonar somehow interfered with normal behaviors or in some instances may have led directly to the deaths of the marine animals. The first cases actually antedated the Bahamas incident, but without "smoking guns" could only be correlated with naval activity and not conclusively causally linked. The first of these events happened in May 1996 near Kyparissiakos, Greece. Twelve Cuvier's beaked whales stranded at the same time that the NATO ship *Alliance* was nearby conducting tests as part of a Shallow Water Acoustic Classification exercise. The subsequent NATO investigation into the incident concluded that "An acoustic link can neither be clearly established nor eliminated as a direct cause for the May 1996 strandings." Although some of the animals were necropsied by the Hellenic Cetacean research and conservation Society, results were inconclusive, "Because of the

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[155] Ibid. (accessed).
[156] Environment News Service, "Washington State Moves to Protect Orcas," April 06, 2004 (accessed April 06, 2004); available from http://www.ens-newswire.com/ens/apr2004/2004-04-06-09.asp.

lack of comprehensive necropsy and complete tissue analyses, the possibility of a pathological cause for the strandings cannot be eliminated."[157]

An article published in the journal *Nature* in 1998 raised the issue beyond an internal review of the strandings, and prompted NATO to convene a Bioacoustic Panel of National Experts to review the incident. The SWAC testing involved a Towed Vertically Directive Source that operated at two frequencies, a 600 Hertz source that radiated at 228 dB and a 3,000 Hertz source that radiated at 226 dB. The investigation estimated that with the source at a shallow depth (20 meters) sound pressure levels of 140-150 dB were estimated to be present at a range of 50 kilometers; at intermediate depths (85 meters) sound levels of between 150 dB and 160 dB were also estimated to be present at approximately 50 kilometers from the source; at greater depths (600 meters) bathymetry limited the range of the signals. Environmental analysis of the Kyparissiakos Gulf found "no direct evidence of anomalous oceanographic or meteorological conditions at the time of the strandings or of other environmental factors which might have played a part;" researchers determined that, "On the basis of the evidence, we are unable to conclude whether environmental conditions contributed directly to the strandings of Cuvier's beaked whales. While it is clear that conditions in the water column were able to support acoustic propagation to long ranges, water temperatures, salinities and sound velocity profiles were all consistent with the seasonal norm for the area." Passive acoustic recordings were made at the time of the testing to listen for marine mammals, but the only animals noted were sperm whales at a distance greater than three kilometers from the source and "No modifications in their vocalizing behavior, possibly related to the SWAC trials were observed." Researchers noted that "It was neither possible to identify other cetacean species because of the too narrow bandwidth available, nor to determine the presence, or absence, of Cuvier's beaked whales because their species-specific sounds are not known."[158]

NATO's Supreme Allied Command Atlantic (SACLANT) Undersea Research Centre (SACLANTCEN) had conducted acoustic testing in the Mediterranean since 1981. From 1994 through

[157] NATO SACLANTCEN Undersea Research Centre, *SACLANTCEN Bioacoustics Panel Summary Record and Report* (La Spezia: NATO SACLANTCEN Undersea Research Centre, 1998).
[158] Ibid.

1996, the center had conducted five sea trials using the TVDS source off the coasts of Spain, Italy and Greece as part of the Shallow Water Acoustic Classification series. After review of these other tests and available stranding data, the investigatory panel concluded that, "Available data indicates that there were no other occurrences of strandings (single or mass) that were coincident in time and location with the other trials that used the TVDS source in the Mediterranean." While the Bioacoustic Panel of National Experts was unable to identify a causal relationship between the SWAC testing with the TVDS source and the strandings at Kyparissiakos, it nevertheless took a precautionary approach to future acoustic investigations. In addition to its findings, the Panel recommended that since "The effects of sound on marine animals vary according to species…additional research is needed to determine hearing characteristics and behaviour of the entire range of marine species." In addition, "With regard to high intensity acoustic sources, there was a strong recommendation from the panel that appropriate environmental assessment procedures be implemented as soon as possible with a view to recommending suitable mitigation and monitoring protocols."[159]

Concurrent with its report on the strandings, NATO promulgated two protocols: the SACLANTCEN Human Diver and Marine Mammal Environmental Policy, and the SACLANTCEN Human Diver and Marine Mammal Risk Mitigation Rules. The environmental policy recognized a sea change in outlook on the use of underwater acoustic sources, "Those who utilize sonar and explosives in the course of their work at sea must now not only be concerned with the impact the marine environment has on sound propagation but also the impact such acoustic energy and explosive shock waves may have within the marine environment, especially on divers and marine mammals. Environmental complacency is no longer acceptable." The policy established directives for future SACLANTCEN research, "In the absence of any other overarching regulations, SACLANTCEN will conduct its at sea research operations in a responsible manner. This will include an Environmental Scoping Study (ESS), mitigation procedures and monitoring together with an associated auditable trail. To this end, all operations conducted on or off the two research vessels, ALLIANCE (German flag) and T-boat (US flag) and/or from islands or beaches in the littoral, are to be conducted in accordance with applicable environmental laws, local regulations and accepted maritime

[159] Ibid.

practice." The policy dictated that "Prudent precautions to minimize any impact on the marine environment and thus to circumvent the potential harm to human divers and to marine mammals from high level sound sources, whether of explosive or electro-mechanical origin, are to be followed."[160]

SACLANTCEN's mitigation rules followed a similar vein as those established under the LFAS program of the United States. As discussed in its policy, Environmental Scoping Studies would be required of any testing that was to be conducted. Previous research in a given area was to be consulted; marine mammal distributions and behavioral patterns were to be estimated; acoustic modeling and forecasts were to be conducted; wrecks, dive sites and swimming beaches were to be taken into account; warning notices were to be prepared and promulgated as necessary; visual and acoustic monitoring would be conducted; and an audit trail of all preparatory and precautionary measures would be maintained and included with research reports. A diver exclusion zone of five kilometers was required for operation of any high level sound source, and a received level of 150 dB established as the maximum exposure level acceptable for any divers in the region, as estimated through propagation modeling and from on-scene measurements of sound fields. The policy established protective levels for marine mammals at an intensity even more conservative than that established under the U.S. program, "As a general rule of thumb, marine mammals should not be ensonified at levels above 160 dB re 1µpa at the reception point." For safety, and utilizing the nominal source level of the TVDS source as its baseline, the policy established a two kilometer buffer zone around the sound source at which point it was estimated that source levels would have attenuated to the 160 dB maximum exposure limit, a figure that the policy estimated was "a conservative bias as a safety measure to protect mammals…with an ample margin of assurance…in all frequencies." [161]

According to NATO's mitigation rules, research scientists were to consult with local authorities to learn about the particulars of the regions in which they were to operate; post trained visual and acoustic monitors before, during, and for a period after acoustic testing was conducted; minimize nighttime operations to optimize visual observations; plan tracks and operations to provide mammal escape routes and avoidance of embayment; avoid coastal areas with steep topography; and comply with all planning and accountability

[160] Ibid.
[161] Ibid.

requirements associated with the provision for providing an auditable trail of their efforts. Scientists were advised to take into account the various surfacing patterns of marine animals, including variable dive times by species, and to avail of all available monitoring capabilities including aerial spotters if available. Acoustic ramp-up techniques were to be utilized to allow animals to depart the area before full power transmissions were conducted, and transmissions were to be terminated if animals were localized within the two kilometer safety zone.[162] While SACLANTCEN's actions indicated that it fully intended to continue its research with underwater acoustics, it took deliberate steps to indicate that it intended to be a good steward of the environment.

The SACLANT Undersea Research Centre was not the only NATO element involved in the utilization of underwater sound as part of its activities, nor the only NATO activity to experience a problem. NATO naval forces regularly conducted ASW exercises similar to those of the U.S. Navy – and that in some instances included vessels from that Service. In at least two of these exercises, marine mammal strandings added to the evidence that naval sonars somehow affected the animals. Only a few months after the Bahamas stranding incident involving the U.S. Navy, three Cuvier's beaked whales stranded on the island of Madeira during a NATO exercise called Linked Seas 2000. In this instance, "The pattern of injury to the auditory system of the stranded whales was consistent with that observed in the Bahamas strandings."[163] It was not the first time strandings had occurred in the general vicinity coincident with offshore naval exercises. In 1991 in the journal *Nature* two researchers questioned whether strandings of beaked whales that occurred on the coasts of Fuenteventura in the Canary Islands in 1985 and 1986, as well strandings which took place on the nearby island of Lanzarote in 1988 were not associated with military maneuvers taking place offshore. Additional strandings in this region in 1989 had been recorded with "naval vessels clearly visible out to sea." The scientists reported that "Local people have only been aware of such military manoeuvres three times since 1985; on each occasion mass live strandings have occurred." In these instances, "No pathological examinations were conducted on any of the stranded animals, but there were no apparent abnormalities or wounds." While the authors felt strongly that a correlation existed between the

[162] Ibid.
[163] Buck and Calvert, *Active Military Sonar and Marine Mammals: Events and References*.

strandings and the military activity, because “Very little is known about the biology of *Ziphius* [beaked whales]…the reason for the unusual strandings can only be the subject of speculation.”[164]

In September 2002, again on the islands of Fuenteventura and Lanzarote, another mass stranding event occurred in connection with a NATO exercise, Neo Tapon 2002. Strandings were reported approximately four hours after sonar transmissions began from a multinational fleet offshore. Canary Island authorities requested that NATO stop the exercises which involved some 30 vessels and ranged between the Canaries and Gibraltar.[165] Necropsies of the fourteen beaked whales (Cuvier’s, Blainville’s and Gervais’) that beached indicated that the animals had “lesions…consistent with acute trauma due to *in vivo* bubble formation resulting from rapid decompression sickness.” It appeared that the whales had succumbed to a condition experienced by divers known as the bends, a finding “challenging the view that these animals do not suffer decompression sickness.”[166] Two causal scenarios were theorized, the first in which “the bubbles could have formed because the deep-diving whales, startled by sonar, surfaced too quickly or changed their diving patterns…[which] would have caused the nitrogen accumulated in their tissues to come out of solution and create bubbles large enough to block arteries;” the second scenario speculated that “the sound waves increased bubble formation as they passed through tissue. Mathematical modeling has previously suggested that sonar could interfere with the ability of tissue to safely store nitrogen under pressure.”[167] While it remained for the exact mechanisms to be worked out, circumstantial evidence tying sonar to whale strandings was becoming ever more convincing.

With more marine mammal strandings taking place and growing national and international recognition over the potentially injurious interactions between sonar and marine mammals, environmental groups pressed their case against the Navy’s program of Low Frequency Active Sonar in the United States. While

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[164] M.P. Simmonds and L.F. Lopez-Jurado, "Whales and the Military," *Nature* 351, no. 6326 (1991).
[165] Ted Harrison, "NATO Blamed for Dead Whales," September 28, 2002 (accessed May 07, 2003); available from http://www.guardian.co.uk/international/story/0,3604,800587,00.html.
[166] P.D. Jepson, M. Arbelo, R. Deaville, I.A.P. Patterson, P. Castro, J.R. Baker, E. Degollada, H.M. Ross, P. Herraez, A.M. Pocknell, F. Rodriguez, F.E. Howie, A. Espinosa, R.J. Reid, J.R. Jaber, V. Martin, A.A. Cunningham, and A. Fernandez, "Gas-Bubble Lesions in Stranded Cetaceans," *Nature* 425, no. 6958 (2003).
[167] Rob Edwards, "Military Sonar May Give Whales the Bends," October 08, 2003 (accessed November 05, 2004); available from http://www.newscientist.com/news/print.jsp?id=ns99994254.

most of the recent evidence linked *mid-frequency range sonars* to marine mammal injury, opposition groups still felt that not enough was known about marine mammals themselves or about the potential harm that low frequency sound might inflict upon them despite the ongoing studies by the Navy and the still extant ATOC/NPAL program. After the Navy was reissued authorization by the National Marine Fisheries Service to take marine mammals in the conduct of its LFAS program in August 2003, environmentalists renewed their efforts in the case that had remained open since the previous Fall under a temporary injunction that limited the Navy to specific regions of the Pacific in the conduct of their tests and operations. That month two Letters of Authorization had been given to the Navy, one for operations onboard *R/V Cory Chouest* and another for operations onboard a ship specifically designed for the operational use of LFAS, *USNS Impeccable*. Both letters stipulated operations in accordance with earlier rule-making on the part of NMFS, and the Navy remained bound by its earlier agreements in relation to the still-pending litigation with the NRDC-led group of environmental organizations.

Within a few weeks of the issuance of the authorizations, the federal judge in the ongoing court case issued an opinion that the National Marine fisheries Service had violated a number of laws in issuing the Navy the LOAs, and ordered the opposing sides of the lawsuit once more to the negotiating table to hammer out an agreement that would allow the Navy to operate LFAS, but in some limited fashion that would be acceptable to both sides on a permanent basis. The judge indicated that she had taken into account the Navy's need for the system to prosecute quieter diesel submarines, but also opined that a balance was necessary between national security requirements and safeguards for marine mammals and other ocean creatures. Although NMFS had agreed with the Navy that its studies and monitoring and mitigation efforts met a reasonable standard to allow the deployment of the sonar *without* the restrictions that had been imposed by the temporary injunction and the interim agreement the Navy had negotiated with environmental opposition groups, the judge disagreed. In her opinion there was still opportunity for interference with critical behaviors that might endanger species of whales and other marine animals such as sea turtles; the judge decided that the Navy had also "arbitrarily and capriciously" ignored studies that low

frequency sonar might kill fish, and that NMFS had failed to consider these effects in making the authorizations.[168]

Faced with a potential outright ban if the judge ruled in the plaintiffs favor, the Navy returned to the negotiating table to work out details of a permanent injunction. In the end the agreement was much the same as the temporary injunction; the Navy agreed to only use the LFAS system in areas of the western Pacific during peacetime – no restrictions were placed on the Navy in time of war – and also agreed to seasonal limitations designed to minimize effects during marine mammal migration periods, and in the vicinity of coastlines. At last environmental opposition appeared to be satisfied with the results; lead NRDC attorney Joel Reynolds stated his concurrence, “This agreement safeguards both marine life and national security. It will prevent the needless injury, harassment, and death of countless whales, porpoises and fish, and yet allow the Navy to do what is necessary to defend our country.”[169] Low frequency sonar appeared to be relegated to background noise for the time being; the same could not be said for mid-frequency range naval sonars…

Every two years a large naval exercise is held near the Hawaiian Islands, a joint venture that pairs naval forces of the United States with allied countries from around the Pacific basin. Early on the morning of July 3, 2004, while two ships of the U.S. Navy and four ships of the Japanese Navy were conducting a exercise using mid-frequency sonar offshore as part of RIMPAC 2004, some 200 melon headed whales entered and nearly beached in Hanalei Bay in distress. Local members of a kayak club managed to herd the creatures back offshore but one young whale died. It was not a normal event by any standards; only one previous beaching of this nature had occurred previously…in the 1850s! When the ships were notified of the incident sonar transmissions were ceased. The Navy initially denied that the vessels were operating sonars prior to reports of the strandings. Later when the Navy reported that the vessels had operated sonars intermittently for twenty hours prior to the event - but maintained that the use could not have caused the whales to strand - environmentalists seized upon the Navy’s statements as further evidence of non-

[168] Kenneth R. Weiss, "Judge Limits Navy Sonar Experiments," *Los Angeles Times*, August 27, 2003.
[169] Quoted in Peggy Anderson, "Navy, Environmentalists at Odds over New Loud Sonar," October 20, 2003 (accessed October 20, 2003); available from http://www.navytimes.com/story.php?=1-292925-2317697.php.

compliance with environmental laws including the Marine Mammal protection Act, the Endangered Species Act and the National Environmental Policy Act. [170]

The National Resources Defense Council joined with the International Fund for Animal Welfare, the Humane Society of the United States, and the Ocean Futures Society in writing to the Secretary of the Navy in protest over the Navy's unfettered use of mid-frequency sonars, pointing to the known impact these sonars had inflicted upon whales four years earlier in the Bahamas. Acknowledging the importance of the Navy's role in defending the United States, the group stated that "this mission can and must be served through practices consistent with our nation's environmental laws and, more fundamentally, with the conservation of our natural resources."[171] The coalition of environmental groups suggested that the Navy "could identify low-risk areas for routine training consistent with mission demands, establish safety zones around transmit vessels, and reduce the source level of sound signals."[172] While the Navy maintained that sonar use was not the cause, the National Marine fisheries Service remained cautious, "At this point, we still know very little about what might have made those whales behave so unusually, but saying that sonar played no role might be a premature determination. Even if we can't establish a clear cause and effect, we're having these coincidences of marine mammal behavior around sonar, and we have to ask why."[173]

The National Marine Fisheries Service investigated the Hanalei Bay beaching incident, but the results were not released until almost two years later on April 27, 2006. The timing could not have been more critical. Just the day before, the Navy had taken an important step in the ongoing dispute with the use of mid-frequency sonar and its potential impacts on marine mammals. In preparation for the upcoming biennial exercise RIMPAC 2006, the Navy requested a federal permit to harass marine mammals in the conduct of the event – the first time such authorization was sought in conjunction with the use of mid-frequency range sonar in an exercise. "For RIMPAC '06, the Navy incorporated emergent science into the

[170] Mark Kaufman, "Navy Changes Story but Still Denies Responsibility," *Washington Post*, August 31, 2004.
[171] Quote in Tim Molloy, "Groups Threaten to Sue Navy over Sonar," July 15, 2004 (accessed November 10, 2004); available from http://www.navytimes.com/print.php?f-1-292925-3089970.php.
[172] Environment News Service, "Navy Sonar May Trigger Lawsuit Over Whale Strandings," July 15, 2004 (accessed February 20, 2006); available from http://www.ens-newswire.com/ens/jul2004/2004-07-15-05.asp.
[173] Quoted in Kaufman, "Navy Changes Story but Still Denies Responsibility."

reassessment of the effects of mid-frequency active sonar use. It gets back to the fact that the science is evolving, and based on that evolving science, we feel we're able to assess at this point what we may not have been able to assess previously," stated a Navy spokesman in explaining why the Navy made the decision.[174]

The following day, NMFS released its findings from he events of two years earlier. The NMFS report neither validated nor absolved the Navy, concluding that while the exact cause of the stranding remained uncertain, the Navy's sonar *might* have played a role. In the intervening time since the 2004 stranding, scientists had analyzed environmental conditions, run acoustic propagation models, and reviewed the results of the necropsy of the young whale that had died. The calf had apparently died of malnutrition; and while evidence indicated that the sonar was likely detectable around Kauai for some time prior to the beaching, it could not be proved conclusively that it caused the mass stranding event.[175] The NMFS findings were heralded by both sides as supporting their positions, but environmentalists decided to act before the Navy could once more operate its sonars as part of the RIMPAC exercises. This time the Natural Resources Defense Council banded together with the International Fund for Animal Welfare, the Cetacean Society International, and the Ocean Futures Society in suing the Navy after NMFS issued the Navy authorizations to go ahead with the exercise. So close to the multinational training event, the Navy did not sit by idly. After consulting with the Secretary of Commerce as stipulated under the Marine Mammal Protection Act, the Deputy Secretary of Defense authorized a six-month exemption from that statute for the Navy to operate its mid-frequency sonars during exercises and on ranges and navy operating areas!

Environmentalists fought back hard, with NRDC's Joel Reynolds in the vanguard, "This is an historic and unprecedented retreat by the U.S. Navy from our national commitment to protect whales, dolphins and other marine life. It's not that the Navy can't comply with the law; it's that the Navy chooses not to." The Navy was working on a plan to bring all of its ranges and operating areas into compliance with

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[174] William Cole, "Navy Seeks Federal Permit for Sonar," *Honolulu Advertiser*, April 27, 2006.
[175] National Marine Fisheries Service, "NOAA Fisheries Service Releases Final Report on 2004 Stranding of Melon-Headed Whales in Hawaii," *NOAA Magazine*, April 27 2006.

environmental laws, and claimed that the exemption under the MMPA allowed it time to further these efforts, “The Navy will continue to employ stringent mitigation measures to protect marine mammals during all sonar activities, to include habitat controls, safety zones around ships, trained lookouts, extra precautions during chokepoint exercises, in coordination with National Marine Fisheries Service.” [176] With environmental groups in an uproar, it appeared that RIMPAC would proceed under this unprecedented move…but appearances could be deceiving.

The exemption that had been authorized by the Secretary of Defense temporarily absolved the Navy of responsibility under the Marine Mammal Protection Act, but the MMPA was not the only statute under which the environmental groups led by NRDC sued. On July 3, 2006, two years to the day after the Hanalei Bay stranding incident, a federal judge issued a temporary restraining order that blocked the Navy’s sonar use in RIMPAC 2006 which was already underway off Hawaii. Stating that, “Plaintiffs have submitted considerable convincing scientific evidence demonstrating that the Navy’s use of MFA sonar can kill, injure, and disturb many marine species, including marine mammals,” the judge ruled according to the National Environmental Policy Act. The NRDC’s Reynolds knew he was in a strong position, “Last Friday the Navy did an end run around the law protecting marine mammals, but fortunately this country has more than one law against the needless infliction of harm to endangered whales and their environment. We sincerely hope the Navy will now choose to comply.”[177] The Navy for its part was in a difficult position, with “more than 19,000 sailors, airmen, Marines, soldiers and Coast Guardsmen along with 40 surface combatant ships, six submarines, 160 tactical aircraft, and amphibious forces” participating in an exercise that included important anti-submarine warfare training among its varied events.[178]

While the Navy considered its options, it committed to continuing the exercise using passive sonar for the time being. But the Navy’s Third Fleet Commander voiced his concern, “To survive, to fight and win,

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[176] Quoted in Environment News Service, "U.S. Navy Exempt from Sonar Limits Ahead of RIMPAC War Games," June 30, 2006 (accessed June 30, 2006); available from http://www.ens-newswire.com/ens/jun2006/2006-06-30-09.asp.
[177] Quoted in Environment News Service, "U.S. Judge Blocks Navy Use of Sonar in RIMPAC War Games," July 03, 2006 (accessed July 03, 2006); available from http://www.ens-newswire.com/ens/jul2006/2006-07-03-05.asp.
[178] Ibid. (accessed).

sailors must be proficient at detecting submarines using active sonar from ships, helicopters, airplanes and submarines."[179] With no diesel subs left in the U.S. Fleet, RIMPAC afforded a critical opportunity for the U.S. Navy to train with quiet diesel submarines operated by some of its allies. Labeling anti-submarine warfare the top priority for the U.S. Pacific Fleet the admiral in charge of those forces affirmed the importance of the training, "Being able to exercise and operate our active sonars is key to our proficiency in that critical warfare area."[180] The Third Fleet Commander agreed that training against the diesels was critical, "They are the threat of the future for us in the western Pacific. If I cannot use active sonar which has been demonstrated as truly the only way you can localize a threat like that, then you're going to have problems in the future."[181] With days slipping away, the Navy returned to the negotiating table yet again.

Over the course of two days in early July, the Navy and representatives of the environmental groups that had sued met to discuss alternatives that both sides could agree to in the dispute. On July 7th the federal judge agreed to the terms worked out during the negotiations and vacated the injunction against the Navy's use of active sonar in RIMPAC 2006. The Navy agreed to conduct aerial surveys to look for marine mammals in the vicinity of the sonar exercises, and to station additional observers onboard the ships and ashore to monitor for any unusual activity by any animals in the area. In addition the Service agreed to restrict the operation of sonars within fourteen miles of the shoreline and in areas shallower than 660 feet. A 25-mile buffer zone was also prescribed near the Northern Hawaiian Islands Marine National Monument that had only weeks before been created by Executive Order, an area the Navy stated that it had not planned to operate but confirmed for the concerned environmental groups during their talks. The Navy also agreed to make available a public hotline for citizens to report any incidents related to marine mammals during the course of the exercise.[182] The NRDC attorney and spokesman Reynolds agreed that the terms served the interests of those concerned for the welfare of marine mammals, "This settlement confirms that measures to protect our oceans can and must be part of the Navy's training for submarine defense. Military readiness

[179] Quoted in Tony Perry, "Navy Seeks Options Amid Sonar Dispute," *Los Angeles Times*, July 05, 2006.
[180] Quoted in Gregg K. Kakesako, "Navy Says Order Hinders Training," *Honolulu Star-Bulletin*, July 05, 2006.
[181] Quoted in Kirk Matthews, "Phase Two of RIMPAC Exercises Begins," July 05, 2006 (accessed September 26, 2006); available from http://khon.com/khon/display.cfm?storyID=14542&sid=1152.
[182] Gregg K. Kakesako, "Environmental Deal Struck to Allow Navy Sonar for War Games," *Honolulu Star-Bulletin*, July 08, 2006; Tony Perry, "Navy Agrees to Sonar Precautions," *Los Angeles Times*, July 08, 2006.

does not require, and our laws do not allow, our natural resources to be sacrificed in the name of national defense."[183]

For its part, the Navy was pleased that the exercise was allowed to proceed in an area in concert with allied submarines that would allow the Navy to train in methods of shallow water warfare. The waters around Hawaii were considered a good proxy for zones that the Navy expected its greatest challenges against potential adversaries such as China, North Korea and Iran. More than 40 nations operated diesel submarines and the Navy estimated that some 140 of the craft were operating in the Pacific theater where anti-submarine warfare was now described by the Pacific Fleet Commander as the Navy's number one warfighting priority. The Navy admiral in charge of environmental readiness back in Washington voiced concern over the science that underpinned the lawsuit, but was nevertheless pleased that the exercise was allowed to continue interoperability and tactical proficiency training with navies from Australia, Canada, Chile, Japan, Peru, the Republic of Korea and the United Kingdom in increasingly important littoral environments, "As we progress towards the shore, and use active sonars, it brings us into contact with marine mammals. But we have to train in order to search for submarines in shallow waters." At the same time he also recognized that this would be a pattern that the Navy should expect in future, "We will apply these lessons to other exercises, as it is possible that other environmental groups will follow suit." The needs of the Navy would have to be balanced, he concluded, "Anti-submarine warfare is the Commander of the Pacific Fleet's number one priority, as the danger of submarines is real. We are taking our responsibility to the environment seriously, but we are also serious about protecting our ships and national interests."[184]

Acoustic Interference

While the environmental groups that opposed the Navy's use of mid-frequency range sonar considered this a victory, the case also opened a new front in the controversy as voices that questioned the restrictions

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[183] Quoted in Kakesako, "Environmental Deal Struck to Allow Navy Sonar for War Games."
[184] Katy Glassborow, "USN Agrees Deal on Sonar Use During 'RIMPAC'," July 18, 2006 (accessed September 27, 2006); available from www.navalforces.janes.com.

placed upon the Navy joined the argument. "U.S. military dominance goes largely unquestioned. No army can hold a battlefield against our troops. No planes can ground our Air Force. No enemy ships can challenge our naval dominance. Whales, though are a different story." The President of the conservative Heritage Foundation voiced his displeasure with the actions of environmental groups. He was concerned that restrictions over operating near the Northwestern Hawaiian Islands Marine National Monument was a blueprint for an enemy determined to oppose the U.S. Navy, "Next time we should just draw a map for our enemies: operate here, and we guarantee we won't do anything about it." He went on to discuss the growing Chinese threat, reported to be adding a dozen new submarines built by Russia and constructing 2.5 boats in their own yards to add to a fleet that the U.S. Secretary of Defense warned might eclipse the U.S. undersea fleet within a decade. He also voiced concern that a recent Navy analysis had reported that submarines were increasingly available on the open market – even for sale on the Internet – that might be used by "fanatical terrorist organizations." He questioned whether the U.S. Navy should be expected or allowed to operate without the best training it might be afforded if expected to meet future challenges, "Americans have enjoyed total battlefield dominance for so long that some seem to have forgotten that it must be earned – every day. It shouldn't be given away to protect whales (or any other animals). If we forget that, someday one of our enemies – one who won't care how many whales it kills as long as plenty of Americans die, too – will eventually remind us."[185]

The President of the Heritage Foundation was not alone in his criticism. Another author claimed that what took place during the RIMPAC controversy was a ploy by NRDC and its coalition of environmental groups to create legal precedence for a case it had lodged against the Navy against mid-frequency sonar in October 2005 that remained unresolved, "Despite the Navy's efforts to protect marine mammals during peacetime training, the NRDC's law-fare has continued. As a result, there is a chance court rulings could have the effect of sending sailors underway with no training on how to use the active sonar on their vessels – or how to deal with the use of active sonar by an enemy."[186] An editorial in *Investor's Business Daily* agreed, "It's not just whales and dolphins that should rejoice at the NRDC's efforts, but every rogue state

[185] Ed Feulner, "Deep-six This Idea of Protecting Whales from Navy Sonar," *Chicago Sun-Times*, July 19, 2006.
[186] Harold Hutchison, "Save the Whales!...From Sonar?," July 26, 2006 (accessed September 26, 2006); available from www.tcsdaily.com/Authors.spx?id=1204.

and enemy of the United States. Of more concern to us than the eardrums of marine mammals should be the nightmare scenario of a diesel submarine from North Korea or another rogue state sneaking close to U.S. shores and launching a cruise missile or disgorging an operative to carry a suitcase nuke into a city. Preserving the convenience of whales, or even the lives of whales, is not worth the risk of losing one ship full of American sailors, let alone an entire American city. Perhaps that famous bumper sticker should be amended to read: 'Save the whales – and North Korean submarines.'"[187]

During the RIMPAC 2006 exercise, while environmentalists constrained the Navy's use of active sonar for training, the North Korean government decided to test fire one of its long range ballistic missiles. The test itself was a failure; North Korea was attempting to solve the technical problems of multiple boost phases to attain the altitude to achieve 'intercontinental' status for its ballistic missile arsenal. The missile splashed into the sea. The editorial anger above stemmed from the notion that "rogue" states such as North Korea could and would destabilize international politics by playing political games of brinksmanship.[188] It was a pattern that State repeatedly used in regards to its nuclear ambitions, and one that it also followed in the arena of ballistic missile technology with respect to nearby neighbors Japan and the Republic of Korea - if to date a failure in legitimately threatening the U.S. with being targeted. With regard to its maritime strategy, North Korea possessed many submarines and used them for intelligence and special operations as became apparent in recent high-profile cases where it was revealed that Japanese citizens had been spirited from their homelands in order to train North Korean operatives in language and customs. Other operations delivered commandos to South Korea where they carried instructions to commit suicide rather than be captured – something that happened more than once in the not too distant past.[189]

In the present days of globalization and of diplomatic dialogue that was much more capable of addressing crisis events as a result of modern communications, North Korea seemed unable to modernize or to advance its national strategies past those more akin to earlier decades. The North Korean regime

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[187] "Heads or Whales," July 31, 2006 (accessed September 27, 2006); available from http://www.investors.com/editorial/editorialcontent.asp?secid=1501&status=article&id=239291373026472&secure=151.
[188] Ibid. (accessed).
[189] Andrei Lankov, "Still Waters Run Deep," October 04, 2005 (accessed September 30, 2006); available from http://www.times.hankooki.com/page/opinion/200510/kt2005100416444754140.htm.

played from a different perspective altogether, one that made wariness the best approach in dealing with its unpredictable leader. When international events such as the missile test made the news for a period, or when other disconcerting operations involving modern submarines captured headlines - as when in 2003 a Chinese submarine was discovered on the surface just outside Japanese territorial waters and a year later another Chinese submarine penetrated those limits and subsequently initiated only the second Japanese Maritime Self Defense Force security alert since World War II[190] – opinions here and there flared in support of increased use of active sonars to address the cheap, effective and credible threat that adversaries might put to sea in the form of quiet nuclear or diesel submarines. But by and large more was heard in public forums about the dangers posed by high intensity active sonars to marine mammals.

Even in areas near Japan and Taiwan where potentially some of the highest threats could be identified from Chinese and North Korean opponents, voices spoke out against the use of high intensity active sonars that were being restricted by the courts in U.S. waters. Researchers in Japan claimed that 74 of 76 beaked whale stranding incidents in those islands over the previous forty years occurred in the vicinity of the U.S.-Japanese naval base at Yokosuka. While no specific stranding-exercise "smoking gun" was identified, nevertheless it was an abnormally high correlation of geographic vicinity of strandings with the likelihood of sonar use by naval vessels when operating near an area of naval concentration.[191] Elsewhere in Japan, the Director for the Okinawa Churaumi Aquarium focused on the sound emitted by a diesel submarine instead of the threat it might deliver to his homeland in describing annoyances to whales, "The (diesel submarine) noise is, however, not bad enough to lead them [whales] to abnormal behavior such as mass stranding. On the other hand, sonar causes mass stranding, a behavior that leads them to death." Director Uchida felt that if the mid-frequency sonar had been restricted in its usage for RIMPAC, then it should be elsewhere as well, "It is a very simple logic. It does not matter whether a law exists to restrict it. If it is banned elsewhere, we don't want it in Okinawan waters, either."[192]

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[190] "China's Submarine No Threat to Japan," November 19, 2003 (accessed September 30, 2006); available from http://www.chinadaily.com.cn/en/doc/2003-11/19/content_282937.htm; Sean Curtin, "Submarine Incident Strains Japan-China Ties," November 19, 2004 (accessed September 30, 2006); available from http://www.glocom.org/debates/20041119_curtin_submarine/index.html.
[191] Allison Batdorff and Chiyomi Sumida, "Exercise Pings Differing Opinions On Sonar," *Stars and Stripes*, July 25, 2006.
[192] Quoted in Ibid.

On a visit to that same island in 2003, similar sentiments were voiced to U.S. Secretary of Defense Donald Rumsfeld, but regarding LFAS instead of mid-frequency range sonar. Mid-frequency sonar had been identified with the incidents in the Bahamas and in the Haro Straits of Washington by this timeframe, but had not been subjected to the litigation and restrictions eventually seen related to the controversies over RIMPAC 2004 and RIMPAC 2006. To be certain, LFAS was not the only issue of contention; the local Okinawan government had other grievances to air with the U.S. SECDEF related to the five-decade presence of the Navy and Marines on their island since World War II. Nevertheless, LFAS was a headline story (read: leverage) that provided top cover environmentally for whatever other issues that were on (or under) the table and the Governor of Okinawa called for a ban on the technology, even as Navy officials hinted that it had recently been used to detect a Chinese submarine nearby.[193]

A steady drumbeat of negative publicity over the U.S. Navy's employment of underwater sound technologies continued, but public outcry against sonar was selective rather than uniform when it came to the development of the issue. The March 2000 stranding incident in the Bahamas received a great deal of attention in the United States. It was a visually disturbing event that was covered in many newspaper, magazine and television reports of the American news media. Besides the fact that only U.S. Navy ships had been implicated, it occurred close to U.S. shores and involved many private American citizens that were members of the environmental groups engaged in the rescue attempts. In addition, numerous U.S. scientists and researchers were brought into in the subsequent investigations of the incident. But for some years afterwards while strandings occurred elsewhere in the Atlantic, these did not receive the same attention in the United States. The exercises in which these other beachings took place were run by foreign navies (although in at least some instances U.S. ships were present); perhaps for this reason environmental groups could not gain the same mileage in the American news media – or litigious traction in the U.S. Courts – over strandings caused by foreign navies operating in foreign waters…even if some of the same charismatic megafauna were affected. And to be certain the United States news media soon became preoccupied with other matters after the September 2001 attacks on the United States.

[193] Bill Gertz, "Rumsfeld Defends Use of Sonar to Okinawans," November 17, 2003 (accessed November 17, 2003); available from http://www.washtimes.com/national/20031117-121116-6276r.htm.

Nevertheless at least two other events in the Atlantic took place that affected the U.S. Navy's attempts to train with its mid-frequency systems. These events – a mass stranding of almost forty whales on the North Carolina coastline in January 2005 followed by the beaching of some six dozen rough-toothed dolphins in the Florida Keys in March of that same year – were both reported to have occurred in connection with U.S. Navy operations off the coast involving the use of sonar. In the North Carolina incident in which 34 pilot whales, one minke whale and three dwarf sperm whales died, numerous newspaper accounts linked the strandings with the Navy's activities. But despite these presumptive reports, scientists eventually concluded that the sonar use – five transmissions had occurred within 200 nautical miles of the primary stranding site at Oregon Inlet within the previous three days – could not be conclusively linked to the event. In the end it was determined that other factors including weather, disease and parasites might have been more significant causes for the beachings, and that while a conclusive finding was not evident, "…this is true of most mass strandings." What is more, the scientific team noted that the North Carolina incident was significantly different from other cases such as the Bahamas and Hawaii ones that involved mid-frequency sonar because those events involved the use of multiple vessels and occurred in areas where specific environmental conditions such as use of the sonar in narrow channels might have led to the strandings.[194]

In the Florida Keys incident, the U.S. Navy submarine *Philadelphia* used its high frequency and mid-range sonars to clear shipping traffic while operating near the surface on at least four occasions while operating some 40 miles offshore over the course of ten days in February and March. Coincident with the submarine operations, almost 80 dolphins beached upon Marathon Key. More than two dozen of the rough-toothed dolphins died; some twenty were returned successfully to sea and the remaining animals were cared for in various mammal rescue centers in the Keys and elsewhere in Florida. Initial necropsies did not reveal conclusive evidence of acoustic trauma, and the ongoing investigation continues to seek a

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[194] Brad Rich, "Scientists to Discuss Acoustic Impacts on Marine Mammals," *Carteret County News-Times*, April 24, 2006.

cause either linking the strandings with sonar or identifying another reason for the event.[195] Either way, the occurrence remained strongly linked with naval sonar use and served as another public association of the dangers of active sonar and an obstacle to Navy efforts to continue training with the devices in coastal waters. That was unfortunate for the Navy…as subsequent to the North Carolina and Florida events it announced its decision to move forward with the development of an Underwater Submarine Warfare Training Range (USTWR) off the North Carolina coast.

The Navy's announcement of its intention to construct an underwater acoustic training range was not a new development; the range had been under discussion for almost ten years and the subject of environmental studies in support of an environmental impact statement. It was the draft release of that statement in October 2005 that elevated the range to more public attention as it indicated the Navy's desire to move forward, and came on the heels of the inconclusive but still suspected involvement of Navy sonar with the whale beachings months earlier on the North Carolina coast, as well as the unresolved case over the effects of sonar usage on the dolphin strandings in the Keys. This time the Navy faced new opposition in addition to the expected controversy it anticipated from environmental groups over its plans. National Marine Fisheries Service scientists now joined other groups in criticizing the Navy scientific studies and estimates of effects on marine life, including marine mammals but now also involving other species including fish. Another whale species – the northern right whale, an extremely threatened species with only some 300 surviving individuals – also figured critically in the mix. The Navy estimated that the range – planned for almost fifty miles offshore but expected to cover some 660 square miles of ocean – would not impact right whale migration patterns which it stated were closer to the coastline, but scientists differed and argued that the whales could be found closer to the range. The head of the office that issued protected resources permits for the NMFS weighed in, "These Navy sonar systems are very powerful and have the potential to kill marine mammals – at least in some situations. It wasn't historically perceived as being as

[195] Jennifer Babson, "Key West Dolphins Stranded on Day of Sub Mission," *Miami Herald*, March 08, 2005.

big a problem as we now recognize it is. We consider the death of a single right whale to be further imperiling the species."[196]

While it could never be said that NOAA NMFS had been an ally of the Navy in its efforts to develop and train with its sonar systems, that agency had nevertheless issued permits in earlier instances and had joined with the Navy as the government agents for joint environmental impact assessments. It was reported that strains had developed between the two organizations, and that the NOAA objections to Navy efforts of its Draft Environmental Impact Statement reflected divisions between the two. Named as co-defendants in earlier lawsuits filed by environmental coalitions related to the issuance of harassment permits, according to observers NOAA was making a break from its side-by-side government position with the Navy. It was a stance that was not lost on the Natural Resources Defense Council, often the lead party in litigation regarding sonar. One NRDC spokesman commented on the NOAA position as a willingness to accept evolving science and not adhere to Navy estimates that minimized the impact of sonar on whales and other marine species, "They're an agency with their own institutional integrity. No doubt NOAA – like any other agencies – can bend. But here the Navy is asking them to snap."[197]

In addition to the objections voiced by NOAA to the Navy's plans, the State of North Carolina through its Department of Environment and Natural Resources registered its displeasure with the proposed USWTR. The Department's Director criticized the thoroughness of the Navy's research and claimed that the environmental impact statement didn't take into account the range of potential damage to sea life and coastal resources. Whales were not the only object of concern; potential environmental impacts questioned included effects on other species of marine life and seabirds as well.[198] The NMFS southeast habitat conservation division commented that the underwater transmissions might disrupt spawning behaviors of commercial and recreational fisheries species such as mackerel, tuna, and drum fish. The agency pointed out that species such as silver perch silence their "spawning choruses" when being chased by dolphins

[196] Quoted in Associated Press, "Federal Agency Says WHales Could Die in Navy Sonar Range," *Charlotte Observer*, February 19, 2006.
[197] Quoted in Mark Kaufman, "NOAA Challenges Navy Proposal for Atlantic Sonar-Training Range," *Boston Globe*, February 19, 2006.
[198] Associated Press, "N.C. Environmental Chief Says Navy Sonar Range Study Lacking," *Charlotte Observer*, April 27, 2006.

using echolocation to find their prey; perhaps Navy sonar might produce the same effect and thereby disrupt a biologically significant behavior. The North Carolina Division of Marine Fisheries questioned whether the laying of cables to the range might hurt marine life, or whether that activity or operation of the range might impact commercial fisherman chasing snappers and groupers.[199]

University researchers concurred with state agencies; at a gathering at Duke University to consider the effects of underwater sound on marine life, scientists from other area schools such as the University of North Carolina Wilmington and East Carolina University chimed in their concern for the effects that a sonar range might have on fish populations in economically important areas for both commercial and recreational fisheries, especially as a result of the impact that competing underwater sound might have on reproductive and other biologically significant activity.[200] The Navy's Draft Environmental Impact Statement had concluded that any effects on marine life from the exposure to underwater sound would be temporary, but even this could be deadly according to one researcher, since if that meant that the sound interfered with a fish's equilibrium, orientation or communication it could make them subject to predation.[201]

While the causes of the January 1995 Oregon Inlet beaching remained speculative, and no further evidence in the interim had linked the use of Navy sonars with the incident, nevertheless the potential connection was repeatedly broached in news coverage of the ongoing debate over the USWTR, damaging the Navy's efforts to win over the public – or media - to its point of view. Without exculpatory evidence, scientists and agency regulators remained skeptical and non-supportive as well. As of the present writing, the Navy continues to gather opinions and comments to its Draft EIS, and plans to address them when it issues a Final EIS which better refines the site options and timetable for the effort. If earlier patterns prove any template, the Navy will ultimately achieve its goal within some manner of restrictions, but continued pressure on a sensitive topic has opened other seams in the controversy. Discussions of sonar impacts on marine life earlier had shifted from low- to mid-frequency after the Bahamas incident; with the scrutiny

[199] Bruce Henderson, "More Harm Seen in Navy Sonar Range Proposal," *Charlotte Observer*, May 02, 2006.
[200] Wade Rawlins, "Science Sees Trouble in Sonar," *News and Observer*, August 15, 2006.
[201] Patricia Smith, "Sonar Range Effects on Fish Debated," *Jacksonville Daily News*, August 15, 2006.

over the USWTR plans, the discussion had moved in another direction…from the impact of underwater sound on very specific creatures – marine mammals and other protected species like sea turtles – to almost the entire marine food chain.

Opposition to Sonar Propagates Around the World

With the legal pressure that was steadily being applied by the Natural Resources Defense Council and its environmental coalition partners, the U.S. Navy felt the heat over its position on active sonar on both coasts and overseas. But other events would frame opposition outside the U.S. and make the use of underwater sound for military purposes the matter of international debate, and not just one fought in the U.S. federal courts over Navy exercises and the development of LFAS. To be sure, many of the environmental organizations that opposed the U.S. Navy had international members or affiliations, but while these groups might mobilize individuals or influential lobbies, they could not directly affect or impede the U.S. decision to employ or not to employ the sonar as a matter of international law – that still remained a matter for other states to become involved. Certainly other nations were witnesses to the events that spawned the controversy that had been brewing on the American side of the Atlantic and Pacific Oceans. In some cases their scientists or agencies were participants in activities such as ATOC; the governments of the United Kingdom, China, Russia, France and Italy were reported to have tested LFAS technology and were likely watching with interest as the U.S. struggled domestically with the issue;[202] and incidents in the Bahamas, the Canary Islands, Greece and elsewhere were essentially international incidents because of the flag of the vessels involved and the locations where the beachings took place. The objections voiced by the Governor of Okinawa and the head of that island's aquarium facility indicated displeasure with the use of sonar by the U.S. in Japanese waters, but neither the Japanese Ministry of the Environment nor its Fisheries Agency had regulations to restrict the use of underwater sound.[203]

Various international agreements existed that regulated the introduction of pollution into the oceans, but even if energy was allowed as such a source or argued in that fashion, military exemptions remained the

[202] Jean Kumagai, "Drowning in Sound," *IEEE Spectrum*, April 2006.
[203] Batdorff and Sumida, "Exercise Pings Differing Opinions On Sonar."

trump card, especially for the overarching body of law for the marine environment, the United Nations Convention on the Law of the Sea. One researcher, spurred by her presence at the NATO conference that investigated the 1996 Kyparisssiakos beachings of Cuvier's beaked whales in conjunction with the acoustic research conducted from that organization's research vessel *Alliance*, conducted a comprehensive review of international environmental law and concluded simply that "Presently, there are no rules of international law that specifically address the transmission of sound through the ocean."[204] After reviewing the spectrum of multilateral treaties and agreements, she concluded that they generally deferred the "choice of appropriate policy implements to individual states, and often require additional protocols" that were difficult to effect. Even so, she speculated, specific policy instruments including zoning ordinances and marine protected areas might demonstrate the best success at addressing the problem of underwater sound in the marine environment.[205] There was already precedent for such an approach; the Navy had been specifically restricted in its mid-frequency operations near the Northern Hawaiian Islands Marine National Monument during RIMPAC 2006, and the permanent injunction that had been worked out for the operation of low-frequency sonar had included provisions for not operating in Offshore Biologically Important Areas (OBIAs).

While the controversy over the use of low-frequency sound had percolated for years in the United States over the development of ATOC and LFAS by the U.S. Navy and affiliated research scientists, the issue of underwater noise internationally really only gained traction after the Bahamas stranding incident in 2000 and the subsequent re-examination of the events that occurred in Kyparissiakos Gulf that had taken place a few years prior. Additional stranding incidents related to military exercises that took place in the Canary Islands provided enough evidence for European interests to become aroused even more. Development of low-frequency active sonar technology had proceeded in a number of European states concurrently with U.S. efforts, but by and large these labors did not draw the same level of interest and concern as the U.S. program. When strandings associated with the use of mid-frequency range sonar actually *demonstrated* effects upon marine mammals in European waters – and provided rather gruesome photographs to serve as

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[204] Elena McCarthy, *International Regulation of Underwater Sound: Establishing Rules and Standards to Address Ocean Noise Pollution* (Boston: Kluwer Academic Publishers, 2004), viii.
[205] Ibid., 216-217.

evidence that the danger had very real implications for well-loved creatures of the sea – a related but separate effort to the one spearheaded by environmental groups in the United States grew in Europe opposing the use of underwater sound by navies for anti-submarine warfare.

As early as January 2003 debate in the European Parliament highlighted the dangers that military sonars harbored for marine mammals, but it is evident that at least initially there was confusion over the types of sonars being used and the specific dangers they posed. Discussions and parliamentary debate of both the Canary Islands incidents and the Bahamas strandings implicated LFAS as the technology that was involved, whereas in both of these instances it was mid-frequency sonar that was the potential culprit. The frequency ranges and intensity levels of the sonars that were quoted by one of the more prominent MEPs in the debate were not at all of the specifications for low-frequency systems, and while incorrect were more closely figures that related to mid-frequency range sonars. Geographic restrictions placed upon the testing of low frequency sonars in the United States were accurately stated, although the argument was being made about the damaging effects of mid-frequency range sonars; the MEP noted that while not allowed to test LFAS in U.S. waters, the Navy was authorized to conduct its potentially damaging tests in "other seawaters," perhaps an off-handed reference to NIMBY (not in my backyard) tendencies on the part of the United States.[206]

During these early European Parliament debates, the ranges at which potentially damaging sound intensities were reported to exist that might "tear tissues" were orders of magnitude greater than any of the scientific studies suggested were possible, and the biological damages that were reported to be caused by low-frequency sound were quoted from scientific investigations into the mid-range frequency incidents. While MEPs may have been misinformed over the exact nature of the technologies behind their concerns, they were more aware of potential responsibilities they had as members of a governing body to address the issues; of significance in these debates were mentions of obligations under the Habitats Directive of the European Union to protect the environment and wildlife, and a link that was made with the use of sonar and

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[206] Committee on Environment Public Health and Food Safety, "Debates: Effect of Low-Frequency Active Sonar on Marine Life," January 16, 2003 (accessed November 05, 2004); available from http://www2.europarl.eu.int/omk/sipade2?PUBREF=-//EP//TEXT.htm.

the provisions of the United Nations Convention on the Law of the Sea with respect to the duties of member states to "take all measures that are necessary to prevent, reduce and control pollution in the marine environment from any source."[207] Even more significant, the European Parliament debates represented the first considerations by an elected government body over potential limitations on the introduction of anthropogenic sound into the oceans.

When debate in the European Parliament was renewed the following year in March, medium frequency sonar now was mentioned in conjunction with LFAS as a matter of concern, but there was still considerable confusion evident in that LFAS was again labeled the primary cause of effects in the sonar incidents that were cited in the Bahamas and Canary Islands. Misinformation was not restricted to the frequencies involved; one European MEP stated (incorrectly) that the United States was developing low-frequency active sonar to combat submarines that only it constructed and sold internationally – something that was patently not the case as the system was being developed to combat new quieter nuclear submarines (a combat system that the United States did not produce for export) and diesel submarines which the United States had not built for decades let alone sold in foreign markets. The MEP questioned why it was necessary to construct a sonar system to search for submarines that only the U.S. had the technology to build if European navies that belonged to NATO were allied to the United States Navy? Another MEP argued that despite calls for more research by participants in the debate, enough proof existed to act upon precautionary grounds to establish a moratorium on the use of sonars until additional evidence was added to the body of scientific knowledge to make a more informed decision. This MEP further alleged that low-frequency sounds were known to cause fish to stray into "dangerous zones that threaten their very existence," a matter of great concern given the commercial impacts this had on fishermen and already depleted fish stocks. If MEPS were not concerned for the environment, perhaps they would be for the livelihoods of their constituencies.[208]

[207] Ibid. (accessed).
[208] Committee on Environment Public Health and Food Safety, "Debates: Effect on the Marine Environment of Low-Frequency Active Sonar," March 11, 2004 (accessed November 05, 2004); available from http://www2.europarl.eu.int/omk/sipade2?PUBREF=-//EP//TEXT.htm.

What was clearly evident in the European Parliament debates was that while the primary concern was for the welfare of marine mammals and other marine life – especially as a stated matter of preventing biodiversity loss, and in support of the precautionary principles embedded in the Constitution and espoused in the Habitats Directive which obliged EU member states to take measures necessary to protect cetaceans in European waters - the issue regarding the *potential* dangers of underwater sound which had gained traction in the U.S. as a matter of low-frequency active sonar had been conflated with other sonars that *were* apparently inflicting harm if the results from the Bahamas and Canaries were correct. In the end, any confusion in the particulars on the part of European MEPs involved in the debate was overturned a short time later by the adoption of opposition to all *high intensity* military sonars.

By the time the European Parliament met in October 2004, medium frequency active sonars had been implicated in a number of marine mammal stranding events, even if not conclusively proved as the cause. In addition to the Bahamas and Canaries incidents which had driven much of the debate, the RIMPAC 2004 beachings had occurred during exercises with medium frequency range sonars - although the results of the investigation into that incident were still more than a year away. But European debates – and most definitely the ones in the environmental committee that had deliberated on this issue – often applied the Precautionary Principle when the central issues under consideration were ones for which evidence indicated that harmful effects might be caused by an activity even if they were not incontrovertibly substantiated. In this light, the Committee on Environment, Public Health and Food safety forwarded its recommendations for a moratorium on the use of high intensity naval sonars, and the European Parliament voted 441 in favor, 15 against and with 14 abstentions for the measure on 24 October, 2004. While this resolution would have to be acted upon by the European Commission to initiate any form of legislation on the issue, it nevertheless represented the will of the European Parliament – an elected body that represented over 375 million citizens of 25 European states.

European Parliament Resolution P6_TA(2004)0047 "Calls on the European Union and its Member States to adopt a moratorium on the deployment of high-intensity active naval sonars until a global assessment of their cumulative impact on marine mammals, fish and other marine life has been completed."

The resolution further “Calls on Member States to actively pursue, in the framework of NATO and other international organisations, the adoption of moratoriums and restrictions on the use of high-intensity active sonars in naval operations and the development of alternative technologies.” And it “Calls on the Member States to immediately restrict the use of high-intensity active naval sonars in waters falling under their jurisdiction.” Other provisions of the resolution adopted by the EU Parliament called for Member States to investigate mammal strandings in national waters, to conduct a study of the potential impact on the marine environment of the deployment of high-intensity active naval sonars, and to establish a Multinational Task Force to “develop international agreements regulating noise levels in the world’s oceans, with a view to regulating and limiting the adverse impact of anthropogenic sonars on marine mammals and fish.”[209] While not a binding directive to EU Member States, the resolution was an important first statement on the impact of naval sonars on marine life by an elected body, and represented the near-unanimous sense of parliamentary delegates as to the importance of the issue. It also instigated a spate of actions by other international bodies to address the growing sense that high intensity sonars needed to be restricted if the marine environment were to receive the protections intended by other treaties and agreements already in existence.

Within a month of the European Parliament’s resolution to adopt a moratorium on the use of high intensity naval sonars, another organization made its sentiments known on the subject. A meeting of the member states of the United Nations Environment Program’s Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) at Palma de Mallorca, Spain approved a resolution that called for extreme caution relating to activities that produced intense underwater noise – including military sonar – and recommended that such activities be halted if necessary until appropriate environmental guidelines might be researched and put into practice.[210] ACCOBAMS is a regional agreement that is open to states adjacent to the Mediterranean and Black Seas (or the contiguous Atlantic area) with the intention of increasing awareness of and reducing threats to marine mammals; the

[209] European Parliament, "Naval Sonars: European Parliament Resolution on the Environmental Effects of High-Intensity Active Naval Sonars," October 24, 2004 (accessed November 05, 2004); available from http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML+TA+P6-TA-2004-0047+0+DOC+PDF+V0//EN&language=EN.
[210] Daniel Hinerfeld, "European Parliament Calls for Halt to High Intensity Naval Sonar Use," October 28, 2004 (accessed October 07, 2005); available from http://www.nrdc.org/media/pressreleases/041028a.asp.

agreement was opened for signature in 1996 and entered into force in 2001and has sixteen member states. At its Second Meeting of the Parties, the member states issued a number of resolutions related to the awareness and protection of cetaceans in ACCOBAMS seas; the most widely reported resolution was the "Assessment and Impact Assessment of Man-Made Noise."[211]

Significantly, the resolution noted that "anthropogenic noise is a form of pollution, comprised of energy, that can have adverse effects on marine life from disturbance to injury and mortality." After recalling the various directives that conferred on that body the responsibility to conserve and protect cetaceans, the November 2004 resolution went on to urge its member Parties to avoid introducing anthropogenic noise into the habitat of vulnerable marine species, especially Cuvier's beaked whales; to increase research efforts into the effect of underwater sound on these animals; to provide information regarding protocols or guidelines developed by militaries with respect to the use of sonar "in the context of threats to cetaceans" and the information used to design them; to investigate alternative technologies to the ones that currently used underwater sound to achieve their military or civilian aims; and to recommend to any parties utilizing underwater sound to exercise "extreme caution…in the ACCOBAMS area."[212] The ACCOBAMS resolution was issued only days after the Spanish government announced that it would prohibit military activities that involved the use of sonar within a 50 kilometer perimeter of the Canary Islands in response to the stranding events that had occurred there.[213]

Within a few weeks of the ACCOBAMS resolution, another important statement was issued by an international organization. The World Conservation Congress of the World Conservation Union (also known as the International Union for the Conservation of Nature and Natural Resources, or IUCN) met in Thailand where it issued its own resolution on the effects of anthropogenic noise on the marine environment. This organization self describes itself as the "world's largest and most important conservation

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211 ACCOBAMS Meeting of the Parties, "Assessment and Impact Assessment of Man-Made Noise," 12 November, 2006 (accessed September 30, 2006); available from http://www.accobams.mc/Accob/Wacco.nsf/ef93f0729ea93d48c125677a004dc4dz/491fb7e7d4267c0cc1256f7e004b4ec8/$FILE/E%20Res%202.1b.pdf.

212 Ibid. (accessed); Bridget Jones, "Protecting Whales, Dolphins and Porpoises from the Harmful Effects of Man-Made Ocean Noise," November 12, 2004 (accessed October 07, 2005); available from http://releases.usnewswire.com/getRelease.asp?id=39691.

213 Kumagai, "Drowning in Sound."

network" and is comprised of "82 states, 111 government agencies, more than 800 non-governmental organizations, and some 10,000 scientists and experts from 181 countries in a unique worldwide partnership."[214] Like the ACCOBAMS resolution, the IUCN resolution also noted that underwater noise was a form of pollution (and one that was not restricted by national boundaries), stating that "anthropogenic ocean noise, depending on source and intensity, is a form of pollution, comprised of energy, that may degrade habitat and have adverse effects on marine life ranging from disturbance to injury and mortality." The resolution observed that a number of sources including oil, gas and mineral exploration and production, shipping and military operations had combined to elevate ambient noise levels in the oceans, but highlighted that IUCN members were "Disturbed by reports of mass strandings and deaths of cetaceans coincident with the use of military sonar and with the use of technologies in mineral exploration, and by experimental evidence of physiological and behavioural impacts of sound on several species of fish."[215]

After applauding the efforts of other bodies to identify and take actions with respect to anthropogenic sound in the oceans and noting its own commitments to the protection of the marine environment, the resolution went on to call for measures to reduce anthropogenic noise in the oceans. It expressed support for additional research into the effects of underwater noise on marine species and encouraged "the application of the results of research in mitigating anthropogenic noise pollution." It further entreated "IUCN member governments, through the mechanisms available to them under domestic and international law" to monitor and investigate the impacts of anthropogenic noise on marine species, including strandings and deaths; to develop alternative technologies and require "best-available control techniques and other mitigation measures" to reduce impacts from anthropogenic noise; to "consider how to limit the use of powerful noise sources until their short-term and long-term effects are better understood, and, to the maximum extent possible, to avoid the use of such sources in habitat of vulnerable species and in areas where marine mammals or endangered species may be concentrated;" and "in the case of military active sonar, act with particular urgency to reduce impacts on beaked whales, and other potentially vulnerable species, by restricting training to low-risk areas, and by working diligently toward the development of

[214] "IUCN Overview," 2006 (accessed October 01, 2006); available from http://www.iucn.org/en/about.
[215] IUCN World Conservation Congress, "Undersea Noise Pollution," November 24, 2004 (accessed October 01, 2006); available from http://www.iucn.org/congress/members/Individual_Res_Rec_Eng/wcc3_res_068.pdf.

international standards that regulate its use." In a move that might prove telling to further uses of underwater sound, including naval sonars, the resolution further urged Members to "consider noise restrictions in the management guidelines for marine protected areas." The IUCN noted in its resolution that the United States (which did not participate officially in the proceedings) submitted a statement recognizing that anthropogenic noise may have adverse effects on the marine environment, and that as a leader in funding research and implementing "science-based management programs to assess and mitigate the adverse effects of some anthropogenic sound on marine mammals and endangered and threatened species," supported international approaches to the issue that utilized science-based means of addressing the problem.[216]

Interestingly, in each of the resolutions by the European Parliament, ACCOBAMS, and the IUCN or in the debates and discussions leading up to their promulgation, references were made to the findings of another international organization - one not always held up as a model for the protection of the marine environment: the International Whaling Commission. That organization, at its meeting in the summer of 1994 had through its Scientific Committee arrived at the conclusion that "there was now compelling evidence implicating anthropogenic sound as a potential threat to marine mammals. This threat is manifested at both regional and ocean-scale levels that could impact populations of animals." While the IWC Scientific Committee identified other sound producers such as oil and gas exploration and production activities, it noted that "Since the early 1960s, there has been an increase in the use and proliferation of military, anti-submarine sonars, particularly those in the mid-frequency range (2-14 kHz)…[and that] the weight of accumulated evidence now associates mid-frequency, military sonar with atypical beaked whale mass strandings. This evidence is very convincing and appears overwhelming."[217] The IWC further endorsed a stance more normally associated with environmental groups rather than a forum involved in the international oversight of harvesting cetaceans; it noted that "measures to protect species and their habitats

[216] Ibid. (accessed).
[217] International Whaling Commission Scientific Committee, "Annex K: Report of the Standing Working Group on Environmental Concerns," July, 2004 (accessed January 18, 2006); available from http://www.acousticecology.org/sriwc56.html.

cannot always wait for ultimate certainty levels of scientific confirmation. In such cases it is appropriate to adopt the precautionary principle."[218]

While ACCOBAMS and the IUCN had scientific committees or members to inform its statements, the European Parliament did not have such a group and had instead requested a review of the effects of sonars on marine mammals from an outside organization, the International Council for the Exploration of the Sea (ICES) based in Denmark. While ICES worked on the EP's request, its final report was not ready in time for the parliamentary debates that preceded the subsequent resolution issued by that body in late 2004, which referred instead to the IWC scientific evaluation of the issue in its text. It may be – from the tenor of the debate in the European Parliament leading up to the resolution – that it turned out to be better that the IWC's conclusions were quoted rather than the ICES report which was issued the following year.

ICES paneled a diverse group of marine scientists to address the task it had received from the EP. Among its members were Chris Clark and Peter Tyack, scientists who had worked on the ATOC Marine Mammal Research Program and the LFAS Low Frequency Sound Scientific Research Program. Also on the panel were Alexandros Frantzis, the scientist who had initiated the inquiry into the Kyparissiakos Gulf strandings, and Paul Jepson and Antonio Fernandez, scientists whose researches on the Canary strandings and other cases of strandings throughout Europe were considered the seminal works by MEPs in quoting the dangers of naval sonars to marine mammals. The report was compiled by correspondence – which delayed its completion past the time that the European Parliament acted in issuing its resolution – and each of the authors reviewed material written by the others in completing the report by consensus of opinion.

After reviewing various forms of military and civilian sonar in low, medium and high frequencies, and discussing in some detail the impacts of the use of sonar in the Greece and Bahamas stranding events as well as the rising levels of anthropogenic underwater noise from other sources such as commercial shipping, the ICES Ad-Hoc Group on the Impact of Sonar on Cetaceans noted that "Noise from commercial vessel traffic, by far the most dominant source of anthropogenic noise in the ocean, is

[218] Quoted in Animal Welfare Institute, "Noise Raises a Ruckus at the IWC," July, 2004 (accessed October 01, 2006); available from http://www.awionline.org/whales/iwc/56iwc/56iwc_Report.htm.

continuous, ubiquitous and shows no sign of decreasing. The intense signals generated by various military sonars and seismic operations, although typically operated only for periods of weeks in limited areas, are being used increasingly throughout the world's oceans. There is increasing use of high intensity acoustic sound sources in oceanographic research projects. While none of these individual sound sources has been shown to cause prolonged disturbance to a biologically important behaviour, they could have cumulative effects."[219]

The multinational ICES panel could find no evidence of impact on marine mammals from the use of high frequency sonars that were used as fish finders, for marine survey, or in some military applications such as mine hunting, but which had generally short range even if operated at higher intensities. There was general agreement that mid-frequency sonars had been linked to some still-yet-to-be-fully-explained effects on cetaceans and beaked whales in particular. And of note, "No stranding, injury, or major behavioural change has yet been noted with the exclusive use of low frequency sonar." While much research was still required into the effects of anthropogenic sound on marine mammals and marine life in general, the scientific panel that formed the Ad-Hoc Group on the Impact of Sonar on Cetaceans concluded that "It appears that sonar is not a major current threat to marine mammal populations generally, nor will it ever be likely to form a major part of ocean noise. Sonar can place individual whales at risk, and has affected the local abundance of beaked whales. Sonar deployment seems likely to increase in the future. The need to research ways of mitigating the effects of sonar is a priority for future research and development."[220]

On the other side of the Atlantic, the environmental groups involved in litigation against the U.S. Navy's use of high intensity sonars heralded the statements by international groups as further evidence that sonar was dangerous and needed restrictions if not outright elimination as a technique to hunt for submarines. Responding to the European Parliament's resolution, the NRDC's Joel Reynolds commented, "This is a landmark in the international battle to protect marine life from needless harm and death caused

[219] Chris Clark, Antonio Fernandez, Alexandros Frantzis, Roger Gentry, Jonathan Gordon, Tony Hawkins, Paul Jepson, Finn Larsen, Jeremy Nedwell, Mark Tasker, Jacob Tougard, Peter Tyack, and Tana Worcester, *Ad-Hoc Group on the Impact of Sonar on Cetaceans* (Copenhagen: International Council for the Exploration of the Sea, 2005).
[220] Ibid.

by high intensity military sonar. It is an unequivocal expression of the democratic will of the people of Europe, recognizing that nations can protect their own security and simultaneously safeguard the health of our oceans simply by using common sense steps to prevent injury from high intensity sonar during training and testing. We have a duty to protect marine mammals and other species, not only for their sake but for our own." Frederick O'Regan, the President of the International Fund for Animal Welfare (IFAW) – a group which joined the NRDC in suing the Navy – added, "The increasing use of active sonar by militaries around the world threatens the survival of numerous marine species, including entire populations of whales and porpoises. This is a global problem that must be solved through international cooperation, and the resolution adopted today by the European Parliament is a significant step toward that goal." The joint NRDC-IFAW press release in support of the EP's resolution also pointed out the recent findings by the IWC's Scientific Committee regarding the threat that military sonars posed to marine mammals, labeling the IWC as "the leading international body concerned with the conservation and management of global whale stocks."[221]

Echoing his earlier comments after the EP resolution, NRDC spokesman Reynolds added his praise after the ACCOBAMS statement was released a few weeks later, "Today's action shows that ocean noise pollution – especially from military activities – is one of the top international environmental concerns. We can and must take common sense steps to protect ocean wildlife from injury from high-intensity sonar and other noises. We have a duty to protect marine mammals and other species, not only for their sake but for our own." The IFAW's O'Regan joined him by restating his earlier comments, "The increasing use of intense noise-producing technology for militaries [sic] activities, oil and as exploration, shipping, and shoreline development threatens the survival of numerous marine species, including entire populations of whales and porpoises. This is a global problem that must be solved through international cooperation, and the resolution adopted today by the ACCOBAMS Agreement is another significant step toward that goal."[222]

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[221] Hinerfeld, "European Parliament Calls for Halt to High Intensity Naval Sonar Use," (accessed).
[222] Daniel Hinerfeld and Erin Heskett, "International Agreement Calls on Member States to Curb Military Sonar and Other Noise Technology," November 11, 2004 (accessed October 07, 2005); available from http://www.nrdc.org/media/pressreleases/041111.asp.

Aside from the possibility that the NRDC and IFAW needed more original public affairs specialists, if their press releases were becoming redundant, it was because the more that new organizations and coalitions joined the battle against high intensity sonar, a more coordinated and coherent message was being voiced that opposed the use of high intensity sonars and other forms of anthropogenic underwater noise because of their potential effects on marine mammals and other forms of marine life. When the IUCN resolution echoed the previous two statements, the NRDC declared a trifecta victory for the oceans, "The IUCN resolution is the most comprehensive action on noise pollution ever taken by the international community. It sets a clear path forward for international progress on high-intensity sonar and other sources of intense noise. After two months of action by so many international bodies on this issue, we hope that the United States has begun to get the message."[223]

While international organizations and deliberative bodies made their voices heard regarding a growing concern for the effects of underwater sound on marine life and marine mammals and particular, the United States Navy appeared ever more determined to proceed with its use of both low frequency active sonar and medium frequency sonars in its efforts to locate adversary submarines. Through its repeated statements labeling anti-submarine warfare as a top priority, its regularly scheduled sonar training exercises, annual requests for reauthorization to harass marine mammals in relation to the deployment of low frequency active sonar, and the development of an underwater acoustic test range, there was little sign that domestic or international pressure was swaying its resolve. It was not the only military organization feeling the heat. In February 2005, the Natural Resources Defense Council turned its sights on NATO. Together with Green Cross International, the Humane Society International, the International Fund for Animal Welfare, the Whale and Dolphin Conservation Society and the Ocean Futures Society, the NRDC petitioned NATO and its member states to reduce the harm it was inflicting on marine life by the use of high intensity sonars. The environmental coalition requested that NATO self-impose common-sense measures to reduce harm from sonar exercises, including efforts to avoid the habitats where higher densities of marine mammals could be found including beaked whales which had been determined to be particularly sensitive to medium

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[223] Joel Reynolds and Daniel Hinerfeld, "Major International Body Adopts Ground-Breaking Resolution on Ocean Noise Pollution," November 24, 2004 (accessed October 02, 2006); available from http://www.nrdc.org/media/pressreleases/041124.asp.

frequency range sonars; reduce the intensities of its sonars; and conduct surveys after exercises to assess the impacts on marine life.[224]

It was not the first time that NATO had received such a request. In late 2003, while still in the midst of debates regarding the impacts of high intensity sonars on marine mammals, a delegation from the European Parliament delivered a more forceful message backed up by more than 100,000 signatures from citizens of EU nations. That petition called for a ban on high intensity low frequency sonar altogether (before that body evidently worked out the relative dangers posed by medium frequency sonars as opposed to the developmental low frequency versions), arguing that their use without proper environmental impact studies violated the United Nations Convention on the Law of the Sea. NATO officials met with the MEPs and accepted the petition, but no ban on sonars followed.[225] With a comprehensive policy in place for the conduct of acoustic research after the review of the 1996 Kyparissiakos strandings, NATO's SACLANT Undersea Research Centre continued its investigations and development work, and NATO ships continued to participate in joint exercises that included the use of active sonar for anti-submarine warfare training.

In the summer of 2005 another front was opened by environmental groups in continuing their opposition to military sonars. This time a coalition of more than 140 different organizations linked to form the International Ocean Noise Coalition which lobbied delegates who were meeting at the United Nations regarding the oceans and maritime law to act to protect marine life from anthropogenic noise from exploration activities and from the use of high intensity naval sonars. Addressing their concerns to participants in the United Nations Informal Consultative Process on Oceans and the Law of the Sea (UNICPOLOS), the environmental groups pressed a case for greater international action on regulating anthropogenic noise in the oceans. Their efforts resulted in the inclusion of a statement in Resolution 60/30 *Oceans and the Law of the Sea* adopted by the General Assembly at its 56th Plenary Meeting in November 2005. Through this statement, the General Assembly recognized the issue of anthropogenic noise as a

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[224] "NATO Challenged to Reduce Sonar Harm to Marine Species," February 12, 2005 (accessed March 01, 2005); available from http://www.earthdive.com/front_end/news/newdetail.asp?id=941.
[225] Katy Penland, "Euro MPs Fight for Whales," October 13, 2003 (accessed March 01, 2005); available from http://www.acsonline.org/issues/sound/military-sonars/NATO-EU_ban.htm.

cause for concern, stating that it “Encourages further studies and consideration of the impacts of ocean noise on marine living resources.”[226]

Although the statement in the General Assembly resolution was rather small, the environmental groups considered it a wedge for further international action, and set for their agenda efforts for the UNICPOLOS to recognize the other international actions taken by the IWC, the IUCN, the European Parliament and ACCOBAMS with the intent for engineering an integrated ecosystems approach to addressing anthropogenic underwater noise; to call for assessments that address the impact of noise on marine life; to urge States through the General Assembly and other international bodies to take active measures to “prevent, reduce and control the generation of harmful undersea noise;” to focus on effects in existing marine protected areas (MPAs) and to consider the establishment of new ones; and to apply the Precautionary Principle with regards to the effects of underwater noise on marine life until research better established it with greater certainty.[227]

The IOCN considered UNCLOS to already provide a “solid basis” for addressing anthropogenic underwater sound as a result of its articles regarding the nature of marine pollution and that directed Parties to act to prevent, reduce and control pollution of the marine environment regardless of source, and further encouraged the use of MPAs to tackle this difficult issue. “Marine Protected Areas (MPAs) are one of the most effective means to protect cetaceans and their habitat from noise impacts, especially cumulative and synergistic impacts, and States and intergovernmental bodies should regulate for noise levels within MPAs and other sensitive habitats. Noise impacts should also be considered in the creation of future MPAs. Such areas must be large enough to safeguard essential habitat and migration corridors and to accommodate highly mobile species. Alternatives to MPAs, such as diverting shipping lanes and area/time closures for noise sources, may be appropriate, though may not adequately safeguard the ecosystem.”[228]

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[226] United Nations General Assembly, "Oceans and the Law of the Sea," November 29, 2005 (accessed October 02, 2007); available from http://daccessdds.un.org/UN/DOC/GEN/N05/461/37/PDF/N0548934.pdf.
[227] International Ocean Noise Coalition, "Summary of UNICPOLOS-7," 2006 (accessed October 02, 2007); available from http://www.awionline.org/whales/Noise/IONC/UNICPOLOS-7%20Summary.htm.
[228] International Ocean Noise Coalition, "Position Statement on Ocean Noise to the Seventh Meeting of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea," 2006

The closing months of 2005 saw additional litigation related to the introduction of potentially harmful anthropogenic noise in the marine environment. October saw the not-unexpected introduction of a lawsuit filed by the Natural Resources Defense Council, the International Fund for Animal Welfare, the Cetacean Society International, the League for Coastal Protection, and the Ocean Futures Society as well as its founder Jean-Michel Cousteau as an individual plaintiff, against the United States Navy over the use of medium-frequency sonar. The suit alleged that the use of this type of sonar by the U.S. Navy violated NEPA, the MMPA, and the ESA and hoped to force the Navy to comply with the regulations and standards of these provisions for further use in either testing or training exercises, and hewed closely to the letter a similar coalition of environmental groups collectively sent to the Secretary of the Navy a year earlier in protest over the melon-headed whale strandings at RIMPAC 2004. One of the main outcomes sought by the environmental plaintiffs in addition to general compliance with these laws was greater transparency over future intentions, including the proper preparation of environmental impact studies in conjunction with further testing or training.[229]

As of the present writing in late 2006 this case remains unresolved, but a recent decision by the Navy to begin the process of conducting broad environmental impact statements related to its utilization of mid-frequency range sonars on the East Coast and Gulf of Mexico and in the waters around the Hawaiian Islands indicates that the Service has embraced a more comprehensive view of the issues – or at least, as the Navy admiral in charge of environmental aspects of naval operations observed during RIMPAC 2006, that the Navy needed to approach its activities with the knowledge that it would face continued opposition from environmental groups and decided to move preemptively in that regard. As more inclusive environmental study and review was one of the central goals of environmental groups in bringing the latest round of litigation, they have taken a cautiously optimistic view of the Navy's actions, "The Navy has been resisting doing anything of the kind for close to a decade now. The important thing isn't just that they do environmental review but that they do it well – in a productive way that genuinely aims to minimize

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(accessed October 02, 2007); available from http://www.awionline.org/whales/Noise/IONC/Docs/UN_Position_Statement_for_UNICPOLOS_VII.pdf.

[229] Daniel Hinerfeld, "Navy Sued Over Harm to Whales from Mid-Frequency Sonar," October 19, 2005 (accessed October 02, 2007); available from http://www.nrdc.org/media/pressreleases/051019.asp.

impacts."[230] With a series of public outreach meetings prior to the generation of the EIS's, the public once again has an opportunity to comment on the Navy's plans, and the initiative will likely face a long and contentious drafting stage, but compared to the present state of affairs where the Navy currently observes "no restrictions on where it uses mid frequency active sonar, but…wants to take into account emerging environmental science," it represents a significant shift in Navy policy and apparent willingness to cooperate rather than litigate.[231] What remains to be seen will be whether environmental groups will be satisfied with the Navy efforts or whether they will consider the Navy's initiative merely lip service to more compliant behavior with environmental laws.

While not strictly related to sonar usage, other legal action at the end of 2005 showcased further moves to attempt to enforce compliance with environmental law, but in this instance the case was brought in Europe and targeted countries of the European Union. Acting to uphold the mandate of the EU's Habitats Directive, which requires member States to act to conserve and protect cetaceans in European waters, the European Commission initiated primary litigious steps against Britain, France, Greece, Italy, the Netherlands, Portugal, Spain and the United Kingdom for failing to establish effective surveillance programs to monitor protection of whales, dolphins and porpoises. The Habitats law required these states to establish conservation zones, and to monitor the conservation of protected species and their habitats in general. In the cases of Belgium and the Netherlands, initial review of their programs determined that the monitoring frequency – once every ten years – was insufficient, while in the United Kingdom surveillance was deemed insufficient for both its frequency and for the fact that it only took place in a portion of that country's territorial waters. France, Portugal and Spain were also cited for failing to monitor species in all of their waters where protected species were present and for not including the full range of species requiring protections in their plans. Greece and Italy were included in the litigation for conducting only sporadic measures and for their lack of comprehensive strategies to conduct monitoring programs. In bringing this action, most of the problems noted by the EC over the protection of cetaceans related to

[230] Quoted in Kate Wiltrout, "Navy Plans to Study Effects of Sonar Training on Environment," *Virginian-Pilot*, September 30, 2006.
[231] Ibid.

fishing practices that harmed these animals through bycatch injuries and ensnarement which led to drowning.[232]

The EU legal procedure to enforce compliance was a lengthy one, but unlike other forms of international law had some "teeth" including punitive damages if countries did not act upon the progressively more directive warnings that were issued. Failure to act on the initial written warning issued by the European Commission would initiate more formal proceedings through Letters of Formal Notice; non-compliance at this stage would bring about Reasoned Opinions detailing specific failures and requesting compliance within a limited timeframe. Eventually non-compliant countries could be brought before the European Court of Justice for a decision to require observance of the Habitats Directive at which point a financial penalty could also be applied. While this specific action did not cite sonar or other sound producing activities as part of the complaint, the actions underway to bring countries into compliance with the Habitats Directive were done so with regards to protections for marine mammals. This was the same argument that was made when the EU Parliament passed its resolution over high-intensity sonar; it would not be a far stretch to imagine future action under this same law being taken against countries for failing to enact protections with respect to the introduction of anthropogenic noise in the marine environment. The October 2004 resolution *encouraged* countries to take certain steps, but the Habitats Directive *required* them to act…or face consequences, as was in evidence in the December 2005 filing on related but separate issues.[233]

You Have the Right to Remain Silent

To address the challenges posed by quieter submarines at the end of the Cold War and the new generation of even quieter diesel submarines in the years after that conflict ended, the United States Navy focused its efforts on the realm of underwater acoustics that had earlier delivered success to its anti-submarine forces. When it began down this path with greater emphasis through the CNO's Urgent ASW

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[232] Environment News Service, "Eight European States Hit with Legal Action over Whale Protection," December 20, 2005 (accessed December 21, 2005); available from http://www.ens-newswire.com/ens/dec2005/2005-12-20-04.asp.
[233] Ibid. (accessed).

Research and Development Program in the mid-1980s, it likely did not anticipate that the greatest hindrance to be encountered would be something other than a physical impediment of the ocean environment or a technological hurdle that had to be overcome to achieve an operational system that could extend the detection range against adversary submarines. But that's exactly what happened. The physics and the technology were extant or only needed to be teased a bit further in research and development and then operationally tested at sea; by no means *easy*, the challenge was still one within the intellectual and technical means of ocean scientists and the defense industries working with the Navy on the problem. But as if following a law of unintended consequences, the program ran afoul of environmental concerns to the degree that it was significantly affected…incurring unexpected costs as a result of marine mammal research programs and the required preparation of voluminous environmental impact statements, and suffering lengthy delays in the development and introduction into the Fleet of operational systems because of litigation - which also ultimately delimited their geographic employment, at least in peacetime training and operations.

It is difficult to say, but seems likely that similar obstacles would not have stood in the Navy's way during the Cold War given the severity of the threat that it faced in that conflict. But this was the post-Cold War, and the submarine threat was much more nebulous than the Soviet one; despite the Navy's increasing rhetoric in more recent years, it is still difficult for the American public to perceive submarines as a threat in the same way it could one that was designed to rain nuclear missiles on U.S. cities. In a way, the strength of the post-Cold War U.S. Navy made it difficult to justify a threat that many observers – and opponents in legal proceedings - considered within its capacity to overcome through other means. That the lid on this Pandora's Box was lifted as a result of swords-to-plowshares technology (ATOC) that sought to address a global environmental issue is ironic, as is the fact that initial controversy has largely fallen by the wayside with the attentions that have now been focused on military sonar as an environmental threat to marine life.

When the ATOC program was still news, and when it had entrained LFAS development into the vortex of controversy that had been generated around the potential for anthropogenic sound to be an

environmental issue, the entire affair resonated at low frequencies - even though “no significant harm” was ever conclusively registered in testing or operational use of these systems at frequencies below 1,000 Hertz. It was only later when two incidents that occurred involving mid-frequency sonar use – but that were both initially thought to be low frequency cases – that any harm was linked significantly to high-intensity sonars. This roundabout manner of identifying a potential threat to marine life also has unintended consequences as a result; it is unlikely that mid-frequency range sonars – which are operated by many navies around the world because of their effectiveness in anti-submarine warfare – will disappear soon from the inventories of naval forces. Their use will be exempted if necessary from restrictions as a result of national security. But the greater restrictions placed on low-frequency active sonar may reverberate for a long time to come, when as a result the technology with the greatest promise to reveal whether the oceans are warming regionally or globally as a result of anthropogenic changes in the Earth’s atmosphere remain silent sentinels on the sea floor to the follies of emotional and interest-driven science and public and media manipulation.

Successful litigation in the United States has limited considerably the utilization of low-frequency active sonar, and appears likely to limit the testing, training and operational uses of medium-frequency sonars – although an outright ban on the technologies will not realistically be effected any time soon unless some other “silver bullet” could be discovered to detect adversary submarines or those platforms are effectively banned as instruments of warfare. But the legal restriction of such military technologies is a significant outcome – one that has many implications for other military devices and practices that potentially threaten protected wildlife or that might damage the environment in any number of ways. While litigation regarding the use of underwater sound for military (or scientific) uses began in the United States through cases filed in the federal court system regarding potential violations of U.S. environmental law, the extension of the issues internationally through the actions taken by the European Parliament and international organizations with respect to anthropogenic underwater noise poses potential problems for the U.S. Navy in operating in foreign waters and perhaps even on the high seas. It also represents an asymmetric challenge to naval power in a vein that has not gone unnoticed at the highest levels of the U.S. government.

The National Defense Strategy of the United States of America that was published in March 2005 addressed “vulnerabilities” of this sort: “Our strength as a nation will continue to be challenged by those who employ a strategy of the weak using international fora, judicial processes, and terrorism.”[234] While this statement was likely included because of the controversy stirred regarding the International Criminal Court, it also acknowledged that the U.S. expected challenges to its military supremacy to come from venues that included both international legal challenges and in some other form from “international fora” – which would include the environmental ones that had already recently taken action including the IUCN, ACCOBAMS, and the IWC…if that is where effective leverage might be found. Through making anthropogenic underwater sound an issue internationally in these bodies, nations that might oppose the United States in the naval arena might be more successful in seeing U.S. use of sonar restricted through multilateral treaties or other forms of international law rather than face the prospect of challenging the U.S. Navy in the naval battlespace equipped with these technologies. Certainly the way ahead for such a strategy was not at all unclear…

While not specifically cited as a pollutant in the United Nations Convention on the Law of the Sea, underwater sound has since been identified as such by a number of international organizations and likely will be treated – or at least be considered for treatment - in this fashion in future treaties or agreements. Even though the Sovereign Immunity exemption exists for warships and other national vessels on government service with respect to the marine protections of UNCLOS under Article 236, it is equally likely that the United States and other countries whose navies rely on sonar as a centerpiece of anti-submarine warfare strategy will resist efforts to entirely shackle the use of underwater sound because of the slippery slope of precedent that such agreements would represent for these technologies. But this potential opposition on the part of countries with naval interests does not mean that other states or international organizations will not be able to realize restrictions over the use of intense underwater sound in vast stretches of the oceans through a more roundabout fashion.

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[234] Donald Rumsfeld, *The National Defense Strategy of the United States of America* (Washington, D.C.: Department of Defense, 2005).

In the litigation surrounding the U.S. Navy's use of sonar, federal courts upheld the authority of environmental laws such as the National Environmental Policy Act over areas of the U.S. Exclusive Economic Zone in determining whether this and other laws applied to the Navy's use of the technologies. Such an interpretation of national law in the EEZ is perfectly in synch with UNCLOS statements allowing such jurisdiction - and in fact encouraging such protections for the marine environment on the part of coastal States within their territorial waters and EEZs. With such encouragements, there is little to hamper other nations from enforcing similar laws or drafting new ones to provide environmental protections in these regions extending up to 200 miles offshore. With the prospect that seabed areas up to 150 miles beyond the 200-mile mark may also be included as part of the EEZ under coastal State jurisdiction (or alternately areas of the seabed 100 miles seaward of the 2500 meter isobath to an offshore limit of 350 miles), it is perhaps possible even to include these regions in such protections considering the manner in which sound can penetrate and travel through the seabed; this may be a more difficult battle to substantiate the potential for detrimental environmental impacts from such activities, but not altogether impossible considering the nature of the living and non-living seabed resources which may be claimed through such a process.

What is more, given the transboundary nature of underwater sound, cases may even be made that the use of intense underwater sound sources in international waters outside of EEZs – keeping in mind that the high seas consist of all areas beyond national jurisdiction and under Article 88 of UNCLOS are "reserved for peaceful purposes" - might threaten marine mammals, affect economically important fisheries, or otherwise "pollute" those waters…perhaps further restricting the use of sonars beyond 200 miles. Again, considerations regarding sovereign immunity remain – as does the fact that the focus of this particular study, the United States, is not a party to UNCLOS – but much of the Law of the Sea has to do with establishing a framework for States to deal with one another. Party or not, much of the norms of UNCLOS have been long observed and become common practice for States including the United States; the main thing the U.S. is able to avoid through non-membership is the arbitration process UNCLOS prescribes – although it may voluntarily submit itself to such jurisdiction. But when environmental protections are

prescribed within coastal State's EEZs, the U.S. must decide whether its sovereign use of sonar outweighs its relations with coastal States in violating their national laws.

The enclosure of various other parts of the world oceans beyond territorial seas and EEZs from the use of intense underwater sound might follow a similar pattern to the process outlined above. Strategies suggested by environmental organizations such as the ones endorsed by the IUCN to create Marine Protected Areas (MPAs) that include restrictions over the use of underwater sound appear to be gaining traction among a wide range of regional or specialized international organizations and more recently within United Nations deliberations under the ICOPLOS process. Anthropogenic underwater noise may eventually become regulated in many ocean areas to such an extent that only wartime use would be allowed under national security exemptions – or in any case at least not go unchallenged in all but very few instances. Exemptions under the concept of sovereign immunity would again apply, but use of sonar in spite of environmental protections in areas such as whale migration routes or breeding grounds would be tried in the court of worldwide public opinion…and there a state like the U.S. would have to ask whether use in those instances justified the scrutiny and opprobrium it would be subjected to by allies and potential adversaries alike. Even allies that might otherwise support U.S. strategy utilizing sonar for antisubmarine warfare – or that possess such technology themselves – would be subject to national constituencies and lobbies that could make it politically difficult to (publicly) support.

It is in the context of these types of restrictions that the United States Navy might face increasing limitations over the employment of its sonars in anti-submarine warfare scenarios. It places that Service in a difficult position, having stated emphatically that antisubmarine warfare has risen to the top of warfighting priorities – at least in the Pacific theater. A number of alternate approaches to the undersea detection problem had been investigated before and after environmental impact statements made consideration of such alternatives a required step, and it was determined that underwater sound was the most feasible approach that ocean science could determine. Low frequency sound was found to be the most viable method for extending the range of detection against quiet diesel submarines, and extant technologies utilizing mid-frequency sound the best options for establishing azimuth in localizing

submarine contacts. In numerous forms, underwater sound is used for other naval activities including marine surveys, mine-hunting and for depth sounders as a matter of navigation. All of these naval uses of underwater sound may be argued to have *some* effect on marine life; but while it may be argued that not all underwater sound is the same, it can also be seen from the previous discussion that conflation of the technologies was irrelevant to the response of some governmental and non-governmental organizations in attempting to restrict them. Commercial sources of underwater sound add considerably more to the underwater cacophony, but they are not nearly is easy to oppose as the operations of navies which answer to government authority more simply than attempts to unravel the convoluted world of ownership, international registry, and the daisy chain of economic interests of the shipping industry.

This is where the United States Navy finds itself today – a powerful bull in a china shop with no choice to shop anywhere else. In a sense it is not unfamiliar territory. As a result of the domestic controversies that ensued over applying acoustic means to the military challenges of present day undersea warfare, the U.S. Navy ultimately may face operating restrictions potentially far more restrictive than the ones it opposed during the original Law of the Sea negotiations regarding the extent of territorial seas and passage through straits and chokepoints – Cold War era deliberations that also came about as a result of oceanographic scientific efforts to overcome environmental challenges to naval operations.

ΨΨΨ   ΨΨΨ

ΨΨΨ Chapter 5 Triton: Altimetry, Anti-Submarine Warfare and Climate Change *ΨΨΨ*

Through the ear muffs of the cranial, the muffled thumping of the helicopter blades sounded like an amplified heartbeat; and despite the fact that the SH-60F rotor completed more than 250 sweeps per minute it felt to the author that his heart just might have been in synch. Flashing by the open aircraft door were mile upon mile of devastation – ripped up roads and uprooted or shattered trees; crushed buildings and houses…or empty slabs where they should have been; and here and there a few signs of life moving amidst the debris. The bright sunshine and clear blue skies meant Visual Flight Rules (VFR) applied for the pilots of the helicopter, which was a very good thing since no radars on the ground were operative to assist air traffic controllers in deconflicting aerial contacts in the skies above the wasteland that a few days earlier had been the vibrant Mississippi Gulf Coast. Plowing ashore with cumulative kinetic, convective and latent power equivalent to many nuclear weapons, Hurricane Katrina had spared little in its path.

The clear skies and sunshine on this first day of September 2005 made it difficult to imagine the fury of a few days before when rains were whipped horizontal by 150 mile per hour winds, and surf that was two and three stories above its normally appointed limits battered the sandy beaches and oak-lined streets. Having visited the Gulf Coast slightly more than a week before the storm arrived, the author found that the familiar streets and neighborhoods appeared anything but recognizable as he scanned for surviving structures to help situate the rest in his mind. Well-known landmarks were gone or twisted beyond immediate recognition; often only in retrospect could the remnants of the structure that had just passed below be reconstructed into the memory of what days before had been a house or a restaurant, a bank or municipal building. Approaching Bay Saint Louis from the East a sense of foreboding arose as the devastation became even more marked, with entire city blocks erased from the landscape of Long Beach and Pass Christian and piled in pieces by the elevated railroad tracks that paralleled the coastline a few blocks in from the beach. Surreally a few items like a picket fence here or a mailbox there stood proudly erect as if they had defied the worst that nature had to offer; but these unsullied remnants were few and far between. The trees that remained standing were awash in debris that dangled oddly from limbs in place of

the leaves that had been completely stripped from the branches – shredded bits of plastic and cloth that had been shower curtains, drapes and carpets…or clothing.

As the helicopter flew westward Henderson Point came into view, swept almost clean of the buildings that had crowded this piece of land that formed the eastern entrance to the Bay of Saint Louis. And immediately it was revealed what had been feared but also expected…the two-mile bridge that spanned the waters was gone, as was the parallel stretch of train tracks on an elevated trestle a half-mile seaward of the automobile bridge. The only recognizable portion of the railroad that remained above water was the swing-section at the midway point, aligned perpendicular to the former line of the tracks as if it had been opened to allow boat traffic that might easily have passed now anywhere but at that point. Following above the dotted line formed by the bared trestle abutments to the shoreline, the helicopter crew flared the aircraft where the tracks had formerly gone ashore on the bluff that guarded the western side of the bay. Here the central downtown district of the city of Bay Saint Louis was twenty five feet above sea level only a few tens of yards from the water's edge. Little could prepare someone familiar with this quiet stretch of waterfront for the scene that waited below.

All of buildings that had been perched on pilings above the slope on the beach side of the road that circumscribed the coast were gone, and most of the hillside and sections of the road had been gouged away leaving an abrupt and crumbling cliff that was vertical almost to sea level. The remains of structures on the opposite side of the road where sections of asphalt still remained intact were hollowed out shells whose contents had been forced through their walls to litter the neighborhoods beyond. There in the first downtown block, about fifty yards north of the tracks and some two hundred yards from where they began as a twisted ribbon of steel on the massive stone casement that still stood at the shore, amidst the downed trees and the tangle of flotsam swept into great piles by the storm surge a flash of yellow batten board was discernible. Although it could not be seen clearly among the debris as the helicopter shuddered in its hover, the author knew that at least some portion of his home had survived Katrina's assault. Almost three decades before, the Category V hurricane Camille had left this home untouched. How could this storm prove so much more devastating…?

From CCCP to FCCC…Changing Climate of Uncertainty…Uncertainty over Changing Climate

Aside from the prospective dangers posed by enemy submarines as threats to naval supremacy, another important challenge must be considered to understand the complexity of the modern day security setting for the United States as it relates to the ocean environment. In scale and scope it is a multivariate quandary that places the United States squarely at the center of yet another asymmetric challenge…but this time as David not quite sure about the size of Goliath, exactly what the imposing giant might be capable of, or just what his own responsibility is for bringing this potential threat down upon himself and everyone around him. It is a threat that defies conventional military response yet one that is capable of changing – and threatening - life as it is known not only in the United States but across the globe. The threat stems from the anthropogenic alteration of the natural environment, and the primary publicly debated embodiment of that threat is posed by the still incompletely characterized impact that human actions may have on the world's climate. In the aftermath of the Cold War, with the demise of the political ideological basis for conflict that defined the superpower struggle, security specialists considered the range of threats and challenges that might contribute to the structuring of the post-Cold War security paradigm. In addition to anticipated (and quickly realized) renewal of ethnic, religious, cultural and racial tensions along with more traditional political strife, one element that was added to the field contemplated ways in which environmental factors might contribute to security problems and concerns. Without any great degree of rigor bounding its parameters, this new aspect of security studies was labeled broadly *environmental security*.

As discussed in the opening chapter environmental security is an extremely far-reaching concept that incorporates the various manners that the natural environment intersects with security at any of its referent levels. Early approaches to the study of these relationships sought to parse the ways that environmental issues might lead directly to *conflict*. The most straightforward of environment-security linkages that could possibly incite conflict were identified as disputes that might result from contested access to economic commodities or natural resources important to national economies or at a more fundamental level necessary for basic sustenance and shelter. In a more indirect fashion security specialists also theorized that disputes

could possibly arise as a result of environmental change (anthropogenic or otherwise) that placed stresses on populations leading to displacement or forced migration, thus making them vulnerable and a potential source of social or political unrest; through an additional linkage, these displaced populations might become susceptible to recruitment by other disaffected parties seeking political change and willing to leverage any source of manpower or political clout that made itself available. To this end, various paths related to the depletion or degradation of the environment and resources were investigated – including climate change, but also such processes as desertification, salination of agricultural lands, deforestation and disputes over riparian rights – and through the work of Tad Homer-Dixon, Robert Kaplan and others were mapped to ways that these issues might lead directly or indirectly to conflict. Although the logic behind such linkages is intuitive, the concept has been bogged down by criticism that too much emphasis has been placed on environmental aspects without due regard to other factors at play in the various places around the world that might serve to contribute to specific instances of conflict or to those factors that might ameliorate such environmental challenges via institutional cooperation. Without the "smoking gun" of purely environmentally-based strife, interest in the field never completely took root – especially when other facets of the emerging 21st Century security paradigm made themselves spectacularly evident in September, 2001.

Scientific uncertainty related to complex environmental problems in general and climate change in particular – ambiguity that is always present no matter how "overwhelming" the evidence appears or the "consensus" asserts – allows issues to persist as political battlegrounds that turn on semantics as much as science. Even the term climate change is significant – having replaced the earlier catchall "global warming" – since scenarios that infer that a warming atmosphere may at some point induce a *cooling* effect rather than a warming one leave the entire issue open to verbal punditry. What is more, attempts by scientists to investigate and characterize climate change as a scientific phenomenon first and political problem thereafter are extremely unlikely if not virtually impossible; by its very nature *anthropogenic* climate change involves the impact of societal practice…and consequently *politics*. Once they had been joined the science and politics of climate change could not easily be set asunder for one fundamental reason: economics. Because of the fiscal impact of addressing climate change by altering energy

consumption and practices or through land use and land management controls and other measures - and the attending uncertainty over what mitigating effects may even be realized for the protection of the environment by taking such actions - stakeholders on both sides launched vitriolic assaults and buried the issue under competing claims of scientific (un)certainty. As a result of the bewildering complexity of the science involved and the rancor of competing rhetoric - which lowers the issue from dispassionate debate to something more like a food fight – and the lack of concrete and unambiguous examples to illustrate its importance, climate change as an environmental security problem has been relegated to a lesser spot in the hierarchy of potential 21st Century security concerns below those that are clear and present dangers, and most definitely below the one that has occupied the highest position since September 11, 2001.

Lesser emphasis on environmental security among present concerns does not mean that work to identify ways that environmental problems and challenges such as climate change might lead to conflict have been in vain; even while transnational terrorism has been elevated as perhaps the primary security concern of the present day, environmental linkages retain relevance. When focus shifts away from terror as a specific problem to an understanding that it is a method that has been implemented to exact political change, recognition that environmental alteration or degradation might serve to make populations susceptible to fundamentalist extremism or other divisive movements will gain attention. When issues come to be viewed from a more comprehensive lifecycle or ecological source-to-spear perspective, it may prove that disruption of the process at an earlier stage – in this case possibly removing some percentage of the pool of potential foot soldiers by addressing environmental problems that contribute to their disaffection - precludes the challenge of blunting it at the point. Other security considerations related to climate change are also being measured but unless the environment-security linkages are clear-cut, attempts to paint them as security issues will meet with resistance. Complicating this debate is the element of environmental activism that seeks to *prevent* environmental issues from being represented as security concerns out of apprehension that they will then merely be co-opted as means to funnel money into security initiatives that

do not address the environmental aspects of the problem.[1] To be sure, much work remains to clarify these relationships.

Although environmental security concepts became a subject of interest primarily in the post-Cold War era when the security establishment sought to determine future potential sources of conflict, environmental problems such as climate change did not simply arise in the 1990s as the Cold War ground to a halt. The monitoring of the concentration of atmospheric carbon on Mauna Loa in Hawaii – to many the smoking gun of climate change, even if not uniquely conclusive in deciphering an anthropogenic signal – was begun at the height of the Cold War as part of the International Geophysical Year. Increased carbon dioxide in the atmosphere had already been the suspected agent for a warming trend in global climate blamed on a "greenhouse effect" and was theorized to be a result of human activity.[2] But at that point in the Cold War, there were larger forces afoot that dominated concerns about security, and environmental degradation was not as evident or advanced, as well studied or understood, or of the same impact with a few less billion people in the world to challenge the Earth's carrying capacity.

In varying degrees environmental problems have played a part throughout history – famine and drought for example are certainly not phenomena that have only recently developed – but they did not manifest in the immediate decades after the Second World War to a degree harsh enough to register above the primary political ideological sources of conflict of the Cold War. Significant at some (smaller) scale – perhaps warranting the involvement of non-governmental organizations or some forms of government sponsored humanitarian gestures - they were not flashpoints with enough fuel to kindle strategic anxiety. Environmental problems were often of more importance within the developing Third World than in the First and Second Worlds of the Cold War, and notwithstanding the ostensible desire on the part of the Cold War superpowers and their satellites to influence third party allegiances, some issues remained beyond the ken of the superpower rivalry. This may have been for lack of strategic import or apparent linkages to Cold

[1] Norman Myers, *Ultimate Security: The Environmental Basis of Political Stability* (New York: W.W. Norton & Company, 1993).
[2] Buck, *Acoustic Thermometry of Ocean Climate: Marine Mammal Issues;* Heather Henter, "It's the End of the World as We Know It," *@UCSD*, September 2005, 27; "Ocean Frontier."; Potter, "ATOC: Sound Policy or Enviro-Vandalism? Aspects of a modern media-fueled policy issue."; Sullivan, *Assault on the Unknown*, 240.

War issues, dearth of measurable impact worthy of investment for its broad political or propaganda value, or even because certain problems appeared so intransigent that they were effectively insoluble and therefore not worth the effort within the larger scheme of concerns that existed between the greatest political rivals.

During the Cold War many environmental problems were left to smolder in various locales, unattended by the East or West and with little prospect for becoming conflagrations large enough for the superpowers or the rest of the world community to bother to extinguish. Political capital was spent where it might best buy influence that could impact the dynamic equilibrium between East and West…not for abstractions that might affront First and Second World nations morally if they had the time or inclination without the central distraction of the Cold War balance of power. Consequently, multivariate and complex environmental problems festered unattended and outside the attention of most of the international community in far flung places around the globe...out of sight and therefore largely out of mind – for the moment.[3] Also relevant to this situation was that security was viewed primarily from a state-centric perspective, and environmental problems with security implications had not to that point been characterized as transboundary issues that might cause disputes or incite conflict between those political referents. In a sense environmental intersections with security concerns became more visible as they better fit a complicated shift in post-Cold War security referents that grew to include nebulous subnational, supranational, and transnational entities - the Generations 'X' and 'Y' and 'Z' of political personalities of a globalized information and technology age.[4] As they are intrinsically transboundary issues by their very nature in many if not most cases – and

[3] Avoiding sweeping generalizations, there were specific problems of drought and starvation; epidemic disease; land use changes and population displacements; ethnic, racial, religious and other sectarian strife; and other grudges over borders, riparian rights, and environmental degradation that raged throughout locations in Africa, Asia, Latin America, and elsewhere that fell low on the hierarchy of Cold War importance. In the post-Cold War world, many of these forces have been identified as elements of instability that have come to be seen as security concerns in their own right through new mechanisms of transference. Some of these problems are being addressed as they become perceived as *threats to security*.

[4] The juxtaposition of flexibly defined subnational, supranational, and transnational political entities with Generations X, Y and Z is meant to analogize the contemporary labeling of the somewhat flexibly defined generational cohorts and does not identify direct pairings meant to imply specific relationships. There is some element of intentional allusive comparison, however. The X, Y, and Z generational cohorts at the time of writing places the 'X's as those persons born between 1965 and the late 1970s, the 'Y's from the late 1970s through the early 1990s, and the 'Z's born thereafter and comprising an age group that is largely younger than 15. This last group cannot be left out of any consideration of modern international affairs both because of the enormous demographic bulge it represents in the Third World as well as the

obviously this is the case for global issues such as climate change – environmental problems generally didn't fit concisely within traditional national or even regional political referents because of the uneven impacts they imposed on segments of human society within and across political borders. More recent (post-Cold War) extra-political security referents acknowledge groups within and across borders, as well as groups that act in varied spots internationally that are not geographically contiguous…and prove more analogous to the manner in which environmental problems often manifest.

Debate over potential security impacts of global climate change in particular spans a wide spectrum of national and international interests, although as a natural or scientific phenomenon the subject does not seem inherently a matter of security. Rather it all appears to be more the esoteric account of scientists' efforts to determine how "greenhouse gasses" influence climate change by trapping heat that otherwise would be radiated to space, a process that consequently contributes to the warming of the lower atmosphere. Through a daisy chain of cause and effect that has challenged scientists attempting to characterize the rate and scope of climate change as a matter of anthropogenic responsibility, additional factors come into play which affect how the Earth absorbs and reflects radiation from the sun, how it stores and transports energy, and what affect an initially warming impetus ultimately will have on altering the climate. The initial effects are complicated, and complex thermodynamic feedbacks make the process an amalgam of if-thens, when-thens, and but-thens… Increases in cloud cover (expected in a warming atmosphere) reflect incoming solar radiation, but trap outgoing long-wave radiation emitted back towards space; decreasing ice mass reduces the amount of radiation reflected at the poles, but frees up additional water which has a higher thermal storage capacity; increased global temperatures *might* spread the temperate zone north (changes could prove to be felt to a greater degree regionally, so sweeping uniform statements of this nature may not be accurate), but this also would allow a greater range of forest and other growth that could pull carbon from the atmosphere; increased sea level rise associated with ice melt and thermal expansion of water would threaten coastlines, but also might provide paths for carbon to be

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unfortunate fact that many of these children have been hijacked as slaves and soldiers of many conflicts around the globe – at times part of the transnational security threats under consideration. The fruitful reintegration of these 'children' into their respective societies represents an enormous challenge, on top of the already enormous trials before the international community over sustainable development to support the population growth of the Developing World.

removed from the atmosphere in hydrates or via increased planktonic primary productivity. The changes, effects, and feedbacks are practically boundless and they make it difficult to predict the final outcome – or at least the *dynamic* outcome as it affects human society at a snapshot in geologic time – but the common denominator in any scenario is change, and the factor that connects change to security is resilience…the ability of elements of human society to adapt to changes in ways that threaten or do not threaten the security of other elements.[5]

Complicating the analysis of these sorts of issues is the often transboundary aspect of environmental problems that make solutions dependent on cooperation (or possibly conflict) between affected parties. One important facet of this involves the potential for environmental problems to undermine the carrying capacity of lands to the degree that instigates migrations of refugees, which in turn burdens institutions not designed to handle them and destabilizes situations – especially in instances where migrations become transnational - where indigenous problems might have been capably handled without the complicating factors posed by societal externalities. This particular example speaks to the concerns among environmental security specialists that environmental degradation and or change might lead to conflict directly over resource allocation, or more indirectly though processes such as those mentioned earlier related to population displacement, migration and unrest as well as the recruitment of disaffected persons by other groups channeling that disaffection into conflict – even conflict that is unrelated to the environmental problems that set the process in motion. Societies that can adapt to change through technical and institutional innovation and flexibility would be less susceptible to environmental perturbations, while those that are not would remain more so; hence the notion of resiliency. But resiliency can be a function of rate…and here also there exists the possibility that not only just those particularly vulnerable segments of human populations are at risk. If change were to occur quickly enough to affect concurrently a broad range of concerns – the structure of economies, the habitability of entire regions, rising sea level that inundates coastlines and low-lying islands, etc. - the institutional capacity to respond will be tested even among the most capable nations.

[5] Thomas F. Homer-Dixon, *The Ingenuity Gap* (New York: Vintage Books, 2002).

As the world's largest emitter of greenhouse gases, the United States is viewed as bearing a large measure of responsibility for problems that it may not even face within its proper borders. At the same time because of its enormous wealth, intellectual capacity and technical capabilities the U.S. is essential to arriving at solutions or at least deriving methods to address environmental problems such as climate change. These strengths have been brought to bear numerous times before when environmental challenges manifested…particularly when they were perceived as integral to the nation's security. In making an assessment of whether or not something is a threat to security, the first task that must be accomplished is to determine what the referent is: who or what is threatened; associated "by what, when, where, and how" questions quickly follow thereafter. In this study, the United States was pre-selected as the referent because of its role in applying ocean science to environmental challenges to security throughout its history, from the origins of the science in the 19th century to the present day. Consequently the first question appears to be answered from the outset. *Quod erat demonstratum*, perhaps…but this is not an entirely accurate view for very important reasons.

Although often uneasy in its status as the sole superpower, as a result of this strength the U.S. must contemplate security from a broader vantage point than its own. Understandably, first and foremost it considers its own security proper: the integrity of its borders and institutions and the safety of its people from destabilizing influences or outright assault. By means of its alliances, the U.S. must consider these same issues with respect to partner nations. And perhaps less straightforwardly America must worry about these factors with respect to its greatest potential rivals for power, for instability within these states bodes ill for a peaceful status quo. But still further, because of its global interventions in foreign political and humanitarian affairs, at some level of planning in both military and civilian circles the United States is required to make assessments of these same factors for almost all other countries, and even sub-groups such as ethnic or religious entities and the newer conceptual groupings that are labeled transnational. A post-Cold War statement of U.S. national security policy demonstrates a rather open-ended view that indicates that many factors such as those above should be considered, "The goal of U.S. national security policy is to

preserve the survival, safety and vitality of our nation and to maintain a stable international environment consistent with U.S. national security interests."[6]

The United States can not feign blissful ignorance from suffering and strife in far-off locations that no longer escapes notice if for no other reason than because of the reach of news media in the information age; in view of the interconnected economic, political and social webs in this day of globalization, very few such considerations can be neglected. Security is undergoing a dramatic reappraisal, and as the nation to which many others look for leadership and guidance, financial or humanitarian succor, or even more traditional military security the United States must stay abreast of these factors globally. Through its own political and legislative process, the U.S. Government decides in which situations to intervene through any manner of its ability to project power and influence, but isolation from problems in distant parts of the globe is a luxury that evaporated with some of the same dive-under-the-desk fear that went away with the end of the Cold War. Gone also, however, is the clarity that described the tense yet understandable macro-relationships of that era, replaced by a plethora of considerations and concerns that substantially muddy the waters of international relations. Further complicating the situation - because the U.S. is a deliberative democracy - environmental issues that intersect with security concerns have become the subject of considerable debate between domestic constituencies that view security issues as necessarily trumping environmental ones, or that in the opposite light view security as overwrought concern that is not justified in pushing the envelop of environmental protections put in place only after considerable legislative effort.

As a result of the central position of the U.S. among nations of the world in terms of political, economic and social influence, the transference of environmental-security issues from domestic discourse or limited multinational focus to greater international attention is near-instantaneous or through only a few degrees of separation. Comprehensive assessments of these associations and interactions in all of their arenas would fill volumes, but some important environment-security relationships in the oceans can be examined in the context of this study that bear important considerations for the United States at present and in the coming years. Some of these associations and interactions are reasonably intuitive; others are not nearly so obvious

[6] Chairman Joint Chiefs of Staff, *Standing Rules of Engagement for US Forces* (Washington, D.C.: Department of Defense, 2000), CJCSI 3121.01A.

because of complex feedbacks that defy direct analysis of cause-and-effect. But viewed in the context of what transpired earlier when ocean science and security interests came together in the 19th and 20th centuries as observed in the previous cases of this work, they are intuitive even in their non-linearity – suitable concepts for a fluid realm. While there are distinct differences between processes and events of the present day as compared to what transpired earlier when marine science was engaged to address matters of security, relationships consistently are so interconnected that the account becomes disconcertingly familiar…"like déjà vu, all over again."[7]

A River in the Ocean

"*From which point, apparently, they intend to launch the missiles to divert the Gulf Stream*."[8] In typically over-the-top dialogue and customary *sang-froid*, the fictional supervisor Waverly from the United Network Command for Law and Enforcement (U.N.C.L.E.) in the campy 1960s television series *The Man From U.N.C.L.E.* tells agents Napoleon Solo and Illya Kuryakin about the plan by the pretend international criminal organization THRUSH to alter the climate of the northern hemisphere. Farcical plotline from the overactive imagination of a Hollywood screenwriter…or as in so much of satire is there some element of reality to this otherwise megalomaniacal absurdity? Although the series was entirely fictional, there is something to be learned from both the characters and plot of this episode from the world of 1960s popular American culture. The Cold War was at its height (the episode aired in two parts on television on November 25 and December 2, 1966) even if some of the near-hysteria of nuclear air raids and under-the-desk drills in public schools had abated. Ironically the American public possibly should have been more alarmed at this point of the Cold War, because it was around this time that both America and the Soviet Union had successfully deployed ballistic missile submarines (SSBNs) on regular patrols that threatened each other's cities and not just their frontline military forces. But this also marked the time when the theory of Mutually Assured Destruction began to be realized in earnest because of the survivability of second-strike nuclear forces represented by the SSBNs. With less need to make up for the American

[7] Yogi Berra, "The Quotations Page," (accessed April 13, 2005); available from http://www.quotationspage.com/quotes/Yogi-Berra/.
[8] Video Frame Capture Library, *The Concrete Overcoat Affair*, March 17, 2005 (accessed May 27, 2005); available from http://www.framecaplib.com/mfulib/html/episodes/indices/concrete/text10.htm.

strategic nuclear advantage in Europe such as that which instigated the Cuban Missile Crisis (when the Soviet Union tried to place nuclear missiles in closer proximity to U.S. targets), the U.S.S.R. was less likely to instigate a first strike to level the numerical odds…and the Cold War settled into a standoff fought at the highest levels of politics – and popular culture.

The *Man From U.N.C.L.E.* paired two charismatic agents – one American and one Russian – under the tutelage of an avuncular British sage as allies working for an organization that was implied to be a clandestine branch of the United Nations (scenes where agents return to *U.N.C.L.E.* headquarters flash images of the U.N. Secretariat in New York City). Apparently this connection was made in the minds of the television viewing public as a number of applicants sought to become spies for the United Nations, much to the dismay of that organization.[9] In *The Concrete Overcoat Affair* episode of *U.N.C.L.E.*, the plot to divert the Gulf Stream brought together science, sociology, and security in an interesting fashion. The use of Russian and American agents fighting evil under the auspices of the U.N. – or something like it – spoke to the hope that the two Cold War adversaries might find common ground, and that the still largely untested experiment that was the United Nations held out some promise in a world then shadowed by nuclear war. The criminal organization THRUSH employed an ex-Nazi scientist – who mentioned how he was wanted in Nuremburg – as a convenient foil palatable as a villain to both sides of the Cold War standoff. What is more, an element of the plot entailed the requirement for "heavy water" as an ingredient. Not long after World War II, the public had become aware of Nazi efforts in Scandinavia to obtain heavy water as part of its nuclear weapons ambitions, and of the repeated and eventually successful efforts by the Allies to deny them this critical element necessary to conduct fission experiments ancillary to making an atomic warhead.[10] While the use of heavy water in this television screenplay scenario was fuzzy at best, it played on this element of public awareness and concern over all things nuclear.

Aside from the sociological aspects of characterization and the nuclear pall which overshadowed the times, the specific object of the evil scientist's attentions is the most interesting aspect of this otherwise bit

[9] Kathleen Crighton, *The Man From U.N.C.L.E.: A Retrospective*, January, 1994 (accessed May 27, 2005); available from http://www.manfromuncle.org/kcretro2.htm.
[10] *Radical Responses to Radical Regimes: Evaluating Preemptive Counter-Proliferation* (Institute for National Strategic Studies, 1995), McNair Paper Number 41.

of fluff entertainment: the diversion of the Gulf Stream. The vision behind this plan was to plunge Europe and the United States into an ice age and parenthetically turn Greenland into a tropical oasis where the evil THRUSH would establish its headquarters. Oceanographers would have immediate issues with the vastly simplified charts that THRUSH employed, and no attempt was made to explain in any detail how both of these the continents would be plunged into frigidity while Greenland became downright tropical. And the theory of diverting the Gulf Stream by the use of nuclear weapons was not elaborated…nor was any means for effecting the permanent shift of the Gulf Stream rather than a temporary response to explosions *every mile* along the length of that basin wide current – and nobody seemed to contemplate the *fallout* of hundreds of nuclear warheads… The show was lite fare and the "plot" was just a vehicle for the hi-jinks of two young television teenage heartthrobs, and analysis of these shortcomings is in actuality unfair and somewhat irrelevant. What *is* relevant was the selection of this environmental warfare plot line, that such tactics are germane to events that *did* take place during the Cold War, and perhaps that this scenario has some degree of relevance even into the present.

"If, by changing the flow of ocean currents, the ice caps of both polar regions were to be melted, the average sea level of the oceans would rise 300 feet... If this were to take place…Washington, D.C. would be submerged, almost to the very dome of the Capitol Building." An element of THRUSH's plan? No…it was an estimate of the effects of a scheme championed by the Soviet Union in 1960 to warm the Arctic. "This year, the proposal includes the use of atomic powered pumps to pump water, millions of gallons of it, from the warmer Pacific into the Arctic Ocean… The over-all effect, so they say, would be to raise the average temperature of the North Pole from below zero to about 41º F…" While this theory raised the possibility that "…Ohio could experience winters rivaling Florida…," it also raised the possibility that "…the most powerful adversary of the Free World would gain ice-free ports which would exceed our own in numbers." In a report commenting on the Soviet plan, an American analyst concluded that the proposal would "…probably not be acted upon positively by the United States, at least not until we learn much more about the ocean circulation. It does, however, indicate the importance of one facet of oceanographic

research to the security of the United States."[11] The writer was an officer in the United States Navy, so perhaps it may be that an anti-Soviet bias colored his assessment of their proposal or that he might not have accurately portrayed the results of such a temperature shift if it could be successfully achieved in the manner described. But he was not alone in his concern for the ramifications of such drastic experiments with climate.

"Oceanographers believe that man is approaching the point where he can try large-scale experiments on the ocean. Not all of them like this prospect; they feel that tinkering with the ocean without sufficient knowledge may be extremely dangerous…[and]…are aghast at the project much discussed by the Russians, of using atomic energy to clear the Arctic Ocean of ice…."[12] The entire climate of the northern hemisphere – perhaps the world – was at risk. "Dr. Maurice Ewing of Columbia University's Lamont Geological Laboratory [the same dynamite wielding Ewing of the deep sound channel] believes that the Northern Hemisphere's comparative freedom from continental glaciers is due to Arctic ice. Winds blowing off the Arctic Ocean are now dry, but if the ice were removed, they would become moist, dropping snow on nearby lands…[that]…would pack into ice, and glaciers would start creeping south." Once set in motion, the process might prove irreversible before "icecaps covered large parts of Europe and the U.S."[13] Perhaps this scenario properly completed the scientific basis for THRUSH's plans for turning the U.S. and Europe into frozen wastes and Greenland into a tropical paradise.

Weather modification was the subject of many science fiction stories and plotlines from movies and television during the Cold War. Eventually it became viewed more as the deranged musings of celluloid megalomaniacs intent on ruling or destroying the world rather than the legitimate strategic and tactical considerations of states very much enmeshed in the throes of a global struggle known as the Cold War. Eventually. "The general of tomorrow would like to have his weather made to order: a fog to conceal a surprise attack; dry soil for his armored force; clear skies for the strategic bombers; low clouds to vitiate

[11] H. O. Webster, "Conquering Inner Space: Oceanography - What it is...What it means to all of us.," *Our Navy*, November 1960, 4.
[12] "Ocean Frontier," 52.
[13] Ibid.

enemy tactical air power; a flood to stop an enemy advance."[14] This assessment written for the Office of the Assistant Secretary of Defense of the United States went on to describe that while each of those desires were to that point theoretical, they reflected research that actively sought to characterize the physical processes associated with the "condensation, precipitation, and evaporation, or, in other words, the behavior of water in the atmosphere…" to determine if they might be controlled tactically for warfare.[15] Describing ongoing research on weather modification, Dr. Pierre St. Armand said, "Primarily the work is aimed at giving…the armed forces, if they should care to use it, the capability of modifying the environment, to their own advantage or to the disadvantage of an enemy. Anything one can use to get his way is a weapon and the weather is as good a one as any."[16]

The famous nuclear scientist Dr. Edward Teller informed a Senate Committee that the United States could conceivably be defeated without warfare if the Russians succeeded in modifying weather to produce rain where they wanted and to deny it to the growing regions of the U.S.[17] And Dr. Henry Houghton of the Massachusetts Institute of Technology's Department of Meteorology philosophized, "I shudder to think of the consequences of prior Russian discovery of a feasible method of weather control. An unfavorable modification of our climate in the guise of a peaceful effort to improve Russia's climate could seriously weaken our economy and our will to resist."[18] Long-term Russian desires to build a dam and pump system across the Bering Strait might have improved the weather in Siberia, and extended the geographical limits of crop production northward – and given the Russian Navy some ice-free ports – but it might also have increased the flow of cold water across the top of North America to be channeled into the Labrador Current where it could affect the climate in the Canadian Maritimes, not to mention have unknown implications for Atlantic circulation and the Gulf Stream…[19]

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[14] Helmut E. Landsberg, *Geophysics and Warfare* (Washington: Research and Development Coordinating Committee on General Sciences Office of the Assistant Secretary of Defense (Research and Development), 1954), 7.
[15] Ibid.
[16] Quoted in D. S. Halacy, Jr., *The Weather Changers* (New York: Harper & Row, 1968), 160.
[17] Ibid., 157.
[18] Ibid.
[19] Ibid., 167-169; Webster, "Conquering Inner Space: Oceanography - What it is...What it means to all of us.," 4.

Although weather and climate modification schemes involving the alteration of hydrological cycles and circulation patterns in both the atmosphere and oceans were the subject of a great deal of speculation and worry, most of these ideas remained experimental or on a comparative micro-scale in both time and space. But those were the intentional efforts of man to modify his environment to suit his needs - *unintentional* modification of the natural environment was something altogether different. "Another risky experiment with the oceans may already have been tried inadvertently. The temperature of the earth's surface depends to a considerable extent on the atmosphere's small content of carbon dioxide (about .03%), which permits short-wave sunlight to pass but impedes the escape of longer heat waves into space – the so-called "greenhouse" effect."[20] This passage might easily have been pulled from one of the present day editions of the *New York Times*, but it was written almost fifty years ago in a *Time* magazine article describing the impact of oceanography on national affairs. The ocean scientist Roger Revelle, then-Director of the Scripps Institution of Oceanography, was concerned about the amount of carbon being added to the atmosphere, and the effect that it might have on climate and living conditions in the United States, making some places near impossible in which to live. Even with some temporal lag elevated atmospheric temperature would be eventually mimicked in the ocean, providing feedbacks that remained ill-understood.

Revelle was years ahead of many of the conclusions that have been accepted by many scientists today as established facts: "Man is moving and shaking the great globe itself in spite of himself. We may be disastrously changing the climate."[21] The need for the study of the physical properties of the ocean had been established as a facet of undersea warfare in two World Wars and throughout the Cold War for the ways these parameters affected the transmission of sound - the primary means of detecting submarines - especially across mesoscale thermal and haline ocean fronts and eddies that might shield the approach of an enemy. If that were not reason enough to be interested in ocean dynamics, ambitious schemes such as those suggested by the Soviet Union to alter ocean circulation in order to modify climate made the study of these same features and properties critical for the ways that changes might affect the security of the United States and the Western world. Climate change in the 1950s and 1960s was a subject of interest as a matter of Cold War designs and tensions, and clearly a matter of security interest. However, more for the reasons

[20] "Ocean Frontier," 52.
[21] Quoted in Ibid.

that Revelle voiced than the intentional modification schemes that never reached fruition, climate change has become a subject of intense interest in the present day; what remains to be seen, however, is whether the same climate-national security / national interest link will be established conclusively such that the phenomenon is treated as a matter of security (read: priority) and not just of science.

"Global Warming Could Have a Chilling Effect on the Military." Considering his background as a naval officer in World War II and as the Director of Scripps in the post-War years, this is a statement that might easily have been penned by Dr. Revelle while assessing the impacts of climate change on naval operations. An article he wrote in *Oceans* in 1969 reflected the perspective of an oceanographer who participated in Operation Crossroads at Bikini Atoll in 1946, in which both atmospheric and underwater testing of nuclear weapons was conducted, before he went on to serve as a branch director at the Office of Naval Research and later take the institutional helm in La Jolla. In his *Oceans* article, Dr. Revelle reflected upon the close and multifaceted relationship between oceanography and military requirements, something he described as "The Age of Innocence and War in Oceanography." Many of his reminiscences regarded the personalities involved in the fledgling science, but the accomplishments he recounted were of ways in which these scientists supported naval operations through their research.[22] He was certainly no stranger to naval oceanography, and with his earlier comments above from the late 1950s about man's impact upon the climate as a result of carbon emissions, the notion that climate change might have a chilling effect on naval operations would not have been a stretch from a man speaking at a time when the United States opposed the Soviet Union across the oceans of the world. Revelle in fact later indicated that his interest in atmospheric carbon actually stemmed from his curiosity about scientific observations recorded during the Cold War nuclear testing that took place at Bikini Atoll, and subsequently influenced his decision to hire a young scientist named Dave Keeling to study the parameter.[23]

The opening quote of the previous paragraph is actually the title of an article published thirty-five years *after* Dr. Revelle's article on military oceanography…and forty-five years after he identified the emissions of carbon dioxide as destabilizing atmospheric chemistry to the point that the earth's climate would become

[22] Revelle, "The Age of Innocence and War in Oceanography."
[23] Henter, "It's the End of the World as We Know It."

significantly altered. The article was published in a journal of the United States National Defense University and focused on the potential for climate change to affect the hydrologic cycle through alteration of ocean thermohaline circulation of the Gulf Stream and adjacent areas of the North Atlantic Ocean, and the security implications for such an event. Where most contemporary climate change scenarios focused on atmospheric affects, the article investigated ramifications for environmental changes that took place in the oceans and directly linked these changes to consequences for naval operations. After years of divergence towards more civil applications of ocean science since the end of the Cold War – a direct result of the waning fears about enemy submarines – the article raised once more the importance of understanding oceanic properties for naval warfare. Reminiscent of the heyday of naval oceanography in the post-World War II era, it also heralded the importance of collaboration between experts in science and naval operations – the article was co-authored by the Director of the Woods Hole Oceanographic Institution and a retired U.S. Navy Admiral who spent a large part of his career in antisubmarine warfare.[24]

Mind the Gap…the GIUK Gap

One of the primary battlegrounds of the Cold War is not marked by monuments or easily visited by those who would gaze over its watery expanse. It is a broad area of the North Atlantic Ocean, subscribing something of a triangular region with Greenland, Iceland and the United Kingdom serving as the terrestrial landmarks of its vertices. Soviet submarines were forced to transit this region to seek out patrol stations off the United States East Coast early in the Cold War to be in range of targets in the American homeland, or if they were of the hunter-killer variety to seek out U.S. ballistic missile submarines in their North Atlantic patrol areas even after improved Soviet SSBNs with longer range missiles were able to target American cities from northern waters late in the period. This region became known as the GIUK Gap and the bottom contours of the area together with the oceanographic properties of the water column that abetted the formation of deep sound channels made this a critical chokepoint for detecting the Soviet boats as they made a break from home waters into the Atlantic battleground. It is also the area where the northern

[24] Richard F. Pittenger and Robert B. Gagosian, "Global Warming Could Have a Chilling Effect on the Military," *Defense Horizons*, no. 33 (2003).

reaches of the warm Gulf Stream current spread out after carving a rather defined path along the eastern seaboard of America.

The dynamic tendrils of the Gulf Stream continually shift and the many whorls and eddies that are shed from its path create temporary thermal gradients that make acoustic propagation anything but regular. Because of the relative salinity differences between the warm salty waters of the Stream and the fresher Arctic waters that they intermingled with, haline fronts were of similar importance for acoustic variance. Submariners experienced in the manner in which sound behaves in the water column could use these evanescent features to hide from potential pursuers as they themselves sought out adversaries in the vast North Atlantic. For these reasons the GIUK Gap was the matter of intense study and continuous observation throughout the Cold War. Ships stationed in the region sampled the water column; aircraft deployed expendable bathythermographs and acoustic listening devices known as sonobouys; and satellites provided broad thermal images that were beneficial in that they did not have to interpolate between the point sampling of the ships and aircraft but were limited in that they sensed only the skin of the ocean surface and not the features beneath in which the submariner had an advantage based upon his ability to sample and exploit the third dimension of thermohaline variance. Nevertheless through laboriously collated climatologies and continually updated mathematical models that initialized the computations required by tactical decision aids, antisubmarine forces were not merely blindly searching the watery expanse for foes. Despite the dynamic problem posed by the interaction of the Gulf Stream and other currents that impinged on the area, after years on the playing field there was enough familiarity to make the task more than a crude matter of blind-man's bluff.

In "Global Warming Could Have a Chilling Effect on the Military," Admiral Dick Pittenger and Dr. Robert Gagosian focused on the North Atlantic not only because it specifically included the GIUK Gap, although both were familiar with the significance of the region for the Cold War submarine battle that was waged there. Rather they considered the region because of the significance it has for planetary cycles of ocean circulation, as a source region for cold dense water that sinks at high latitudes and spreads at depth south towards the equator. Sinking regions are important for the role they play in overall ocean circulation

for an obvious reason – if water does not sink there the cyclical pattern of which they are a part is disrupted. The region where the Gulf Stream reaches towards the Arctic is the critical source province for a cycle known as the Atlantic Conveyor. Pittenger and Gagosian consider the potential for disruption of North Atlantic circulation as a result of climate change and take the further step of pondering the effects that this environmental change might have for security interests. It is a multivariate problem.

Disruption of the Atlantic Conveyor might change how heat is transported northward from equatorial regions, something that would have direct consequences for the European climate that benefits from the warming and humidifying effects of the temperate Gulf Stream on the winds that sweep across its surface and then over the landmass to the east. This has a host of ramifications from the habitability of the region and agricultural viability of its heartlands to the accessibility of its ports and transoceanic communications and commerce. And in no small measure there are implications for naval operations throughout the entire region. From the previous discussion it becomes apparent that the acoustic conditions that became somewhat tractable from years of study now would have entirely different patterns based upon the location and strength of thermohaline gradients. This would be true at the surface but also at depth where sinking watermasses spread southwards and influenced gradients far into the Atlantic. What is more, dramatic shifts in ocean currents and wind patterns might make well traveled sea lanes less amenable to transiting vessels. Atlantic storms quickly raise seas beyond safe limits for shipping, but somewhat regular patterns have determined routes that ships ply to decrease the likelihood of encountering these dangerous conditions. Should these routes of relatively safe transit become disrupted because of changes in oceanic and atmospheric parameters, the implications for both naval operations and civilian commerce are enormous.[25]

The NDU think-piece by Pittenger and Gagosian is significant also for the emphasis it placed on the potential *pace* of climate change with respect to security interests. If climate change occurred slowly over time, it is likely that shifts would be detrimental to patterns of human social, economic, and security interests…but manageable. The capacity for technological innovation and adaptation is enormous,

[25] Ibid.

especially in the industrialized nations of the north nearest the region under discussion. On either side of the North Atlantic Ocean there are highly developed nations with centers of research that might bring all their energies to bear on the problem to create adaptive technologies for the societies they serve.[26] But this sort of malleability is predicated on knowing the trends for very important factors: rate, direction, extent and intensity. Rate refers to the pace of change and it is intuitive to expect that given enough time, developed societies might adapt (leaving aside the argument that they didn't see the change because it was *too* incremental or the notion that change was ignored because of any other number of reasons including uncertainty or prohibitive costs of adaptation). Climate change historically was viewed as a creeping phenomenon, something that occurred on more geologic than human frames of reference. We know about ice ages and warm periods but because of paleontological records, and not as clearly through the lens of recorded human history; the uncertainties associated with this type of research offered something of a procrastinator's way out…a reason to wait for more certain evidence. Why undertake the expense required to engineer new technologies or develop new processes if the evidence is not clear enough to justify the effort?

Direction refers to the trend of change; when the issue of climate change first gained traction, it was under the guise of a warming atmosphere related to increasing carbon dioxide concentrations and hence was first discussed as *global warming*. The somewhat improperly applied metaphor "greenhouse effect" leads one to envision only a warmer climate - even to the point where some question why this might be a bad thing if cities such as Boston might enjoy winters more like Charleston - and ignores or fails to sufficiently emphasize the possibility that the ultimate result of a potentially warming atmosphere could be a *cooler* climate. The geographic extent of climate change is also uncertain; there is evidence that the coverage that *global* climate change implies is to some extent misleading since the phenomenon might be significantly more pronounced in certain latitudes or regions, rather than averaged over planetary scales as the catchall leads the typical reader to surmise. Intensity of climate change variability is speculative and dependent on still inconclusive modeling efforts to forecast, although historical evidence provides at least some bounds that are not out of the question; an area of still evolving research, modern paleoclimatology

[26] Ibid.

regularly reveals new extremes from the record that - if they happened today - would seriously affect mankind. In these critical ways, popular understanding of global climate change may be woefully inadequate or misdirected; and the many scenarios that have been sketched that depict the effects of a warming climate ultimately may prove to be OBE – overturned by events. The research into technologies to adapt and to make societies more resilient to a warmer world to may be wasted efforts that are unable to cope with a colder one. The first order of business then would appear to be a need to resolve these parameters or at least have a better understanding of the processes of change that scientists are attempting to discern.

The Puffin in the Coalmine

From the patterns of investigation, discovery and feedback that have been discussed earlier in this dissertation related to the applications of ocean science to naval challenges, it should come as little surprise that the geophysical canaries in the coalmine of climate change have also come to be realized as a result of the interaction of science and security. The theoretical scientific underpinnings behind at least two of the most well-known of these bellweathers may be traced back to lines of inquiry that occurred decades before the Cold War interests that led to their more detailed investigation; it will remain beyond the scope of this study to investigate their specific historical geneses, but the successful detection and tracking of a proposed anthropogenic signal of atmospheric carbon, and the equally consequential cracking of the historical rosetta stone of climate change via sediment and ice cores both have everything to do with man's struggle to gain the upper hand over his fellow. The first of these potential indicators of climate change is epitomized by the widely publicized time series of observations of atmospheric carbon dioxide by Dr. Dave Keeling from atop the volcano Mauna Loa in Hawaii. Dr. Revelle as the Director of Scripps Institution of Oceanography had made public the potential that increasing atmospheric carbon dioxide might be warming the troposphere; Scripps' scientist Keeling gathered the data.

The Mauna Loa series of observations began with the International Geophysical Year of 1957-1958, a Cold War collaboration that sought global observations of many geophysical parameters – ostensibly in the

name of science but supported by budgets of Cold War adversaries that saw the alternative benefit of information in the oceans, atmosphere and space that could be used to support military efforts associated with submarine warfare, ballistic missile technologies, long-range communications, and even potential weather modification as weapons in a pervasive global confrontation that dominated the post World War II period. Participating IGY scientists may have seen the "pure science" benefits of their efforts, but if they overlooked the dual-use nature of their research they did so without respecting the reasons that underpinned the vast government-sponsored research and development of the era. In a similar vein, albeit an effort as geographically and climatically displaced from the tropical location of Dr. Keeling's research as could be imaginable, the other 'canary in the coalmine' of climate change discerned as the byproduct of military research was more likely a puffin. Half a world away from Hawaii on the desolate ice fields of Greenland, research funded by the United States Army led to the first continuous and detailed ice cores which were used to peer through geologic time to sample ancient atmospheres. Once ice core data could be cross-referenced with the many oceanic sediment cores that were drilled to reveal the geophysical secrets of the ocean floor – in part for reasons specific to naval operations already addressed including the influence of seafloor sediments on acoustic propagation – paleoclimates became much more clearly understood.[27] From both of these canaries – or canary and puffin as the case may be – much can be learned about the essential challenges of climate change: rate, direction, extent and intensity.

For anyone that has looked at the Mauna Loa time series that depicts the change in concentration of atmospheric carbon dioxide over time, there is an undeniable trend – upwards. With regular seasonal fluctuations, the series rises from an average 315 parts per million (ppm) of carbon dioxide gas in 1958 to a present day average closer to 380 ppm.[28] The inexorable rise as depicted on a simple and straightforward plot – no fancy colors or graphics are necessary to demonstrate the signal – speaks volumes. If the essentials of a greenhouse gas theory of atmospheric warming are correct and an increase in atmospheric carbon leads to an increase in global temperatures, then the Mauna Loa time series points the way and for its simplicity and early presentation it rightfully deserves recognition as one of the first cries for attention to

[27] John D. Cox, *Climate Crash: Abrupt Climate Change and What It Means to Our Future* (Washington, D.C.: Joseph Henry Press, 2005), 34-37.
[28] C.D. Keeling and T.P. Whorf, *Atmospheric Carbon Dioxide Records from Sites in the SIO Air Sampling Network* (Oak Ridge: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, 2005).

what man might be doing to his environment. Keeling's publications of his initial findings in the early 1960s that atmospheric CO2 had indeed increased during his IGY study was the initial confirmation that the gas was accumulating in the atmosphere; the time series now 40-plus years long has verified steady increases ever since.[29] The slope of this data analogizes aptly a wedge leveraging innumerous other studies that examine influences on the Earth's atmosphere in order to foretell the planet's climate future.

Investigations have now been conducted that explore the impact on the Earth's climate of everything from the effects of variations in solar activity to the addition of methane gas from the flatulence of cows. With each investigation, additional influences and feedbacks describe an increasingly complex climate machine that defies simple description, but that leaves researchers with a sense that change is in the air and that this change does not necessarily bode well for Planet Earth or for mankind. Increasing awareness of climate change as a potential threat to human society led to the negotiation of the United Nations Framework Convention on Climate Change (UNFCCC) at the Earth Summit in Rio de Janeiro in 1992. As a "framework" convention, this international agreement was little more than a statement of the problem that expressed the general consensus that something needed to be done…without getting into the specifics that might have made the agreement more contentious and less universal in its acceptance.

In the intervening years a number of Conferences of the Parties (COPs) to the UNFCCC have further refined the goals of this widely ratified document, but the issue of anthropogenic influence on climate change – intimately connected to the burning of fossil fuels and thus to the economies of developed and developing nations alike – has become one of the most contentious international issues of the day. Global climate change is extremely complex both in its science and its politics, but in broad terms this controversial issue must be understood to fully appreciate the nuanced implications it has with respect to national security and ocean science, especially for the United States. The subject is essentially a matter of three questions: whether the Earth's Climate is changing (including aforementioned factors of rate, direction, extent and intensity); whether man has influenced the rate or direction of change; and what

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[29] Ibid; Charles D. Keeling, "The Influence of Mauna Loa Observatory on the Development of Atmospheric CO2 Research," in *Mauna Loa Observatory: A 20th Anniversary Report*, ed. John Miller (Silver Spring: National Oceanic and Atmospheric Administration, 1978).

should be done at all levels of human society to address the matter. Simple enough…yet nearly impossibly complicated. For the purposes of this case study, the focal interest further telescopes to how the position of the United States in the debate is intertwined with its national security interests, and in particular the ramifications of climate change from a naval perspective.

The U.N. Framework Convention on Climate Change declared that its non-binding aim for its signatory parties was to reduce the atmospheric concentration of greenhouse gases in order to prevent "dangerous anthropogenic interference with Earth's climate system."[30] 154 nations signed the agreement with the ultimate intention of stabilizing emissions of greenhouse gases at 1990 levels by the year 2000. The accord was not called a 'framework' without reason…for it only painted in broad strokes the general intent without getting into particulars about how these goals were to be achieved. The devil was most certainly in the details, and those remained to be worked out at annual Conferences of the Parties (COP) that would take place when enough national instruments of ratification were recorded with the General Secretary for the Convention to come into force; this happened once 50 instruments were received by the Secretariat, in March 1994.

The UNFCCC COP has met eleven times as of this writing, but the direction of this accord had been determined dramatically within the first six meetings. At the time of the Earth Summit in 1992, while the impact of anthropogenic influences on the Earth's atmosphere and climate system remained to be assessed, there was a general sense that man was somehow affecting his environment through various means but primarily through the burning of fossil fuels and the subsequent emission of greenhouse gases into the atmosphere. Realization of the dangers potentially associated with this process was not particularly new – even Roger Revelle's discussion in the 1950s was not a revelation, but rather a contemporary statement of a potential problem identified decades earlier in the 1800s [31]– but after three decades of environmental activism and the sputtering end to the Cold War which allowed international attention to focus away from nuclear détente, there was a window to act. Earlier international environmental agreements had set the

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[30] "United Nations Framework Convention on Climate Change," 1992 (accessed December 24, 2006); available from http://unfcc.int/essential_background/convention/background/items/1349.php.
[31] Henter, "It's the End of the World as We Know It."

stage for treaties for protecting the Earth's atmosphere, including one that regulated aerosols that damaged the protective ozone layer and another that addressed the transboundary responsibility of states for airborne pollutants that impacted upon other states. While the science behind these particular environmental degradation scenarios was far from simple, the specifics of climate change are far more complex because of the many paths and feedbacks that are involved in thermal, geologic, biologic, hydrologic and cryologic cycles that together form the coupled ocean-atmosphere climate system.

Despite the attendant uncertainty involved in discerning the disparate and interrelated effects of these subsystems, there was general consensus that man was in some fashion influencing the Earth's climate system through various practices but largely through burning fossils fuels and the production of other greenhouse gases. Since at even an initial first estimate it was obvious that certain countries were emitting more greenhouse gases than others – the United States was far and away a leading emitter – there also developed a sense of "common but differentiated" responsibilities that needed to be met under any agreement to address climate as an international issue; developed/industrialized nations were grouped as "Annex 1" countries that would (at least initially) take on greater efforts to reduce emissions to meet international goals. While this may have been a statement of the obvious and perhaps even the morally appropriate, it was here where international commitment met national responsibility in this debate…and it was here that the essential disconnect developed in the way ahead.

The Intergovernmental Panel on Climate Change (IPCC) was established jointly by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988 to "assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation." The IPCC was *not* established to "…carry out research nor does it monitor climate related data or other relevant parameters. It bases its assessment mainly on peer reviewed and published scientific/technical literature."[32] In the world of science, where the open publication of data, methodology and results, the "blind" (unbiased) peer review of

[32] Intergovernmental Panel on Climate Change, "Mandate and Membership of the IPCC," 2006 (accessed April 23, 2006); available from http://www.ipcc.ch.

research, and critical debate are essential pillars of scientific research, the IPCC was designed to be above reproach – an unbiased arbiter that collated information that was already accepted science and condensed it for policy makers without bringing particular political baggage to the table. Theoretically. It would be difficult to say unswervingly that the various scientists and policy makers that served (serve) on the IPCC have *no* political baggage or predispositions, but the subject material they work with and the fact that sponsor governments have approval authority over IPCC publications makes personal interpretation and individual stances more difficult to effect.

In a massive undertaking to digest the reams of papers, studies, and reports on climate-related topics, the IPCC produced three synthesis assessments over the course of the climate debate that has been taking place within the UNFCCC COP framework. The First IPCC Assessment Report (FAR) in 1990 was instrumental in establishing the negotiating committee and providing the essential base material for the UNFCCC. The Second IPCC Assessment Report (SAR) was issued in 1995 and was influential in the discussions and negotiations of the early COPs after the treaty came into force. While not being overly specific or too blunt, the SAR put at least some of the blame for climate changes squarely on anthropogenic causes. The critical first element in the whole climate debate was whether in fact man was influencing the climate through his activities, and the Second Assessment – while not unequivocal – stated that "…change is unlikely to be entirely natural in origin…[and that] the balance of evidence, from changes in global mean surface air temperature and from changes in geographical, seasonal, and vertical patterns of atmospheric temperature, suggests a discernible human influence on Global Climate."[33] There was not *conclusive proof*, but there was a sense, and that sense was bringing the international community towards a new principle of international law… The entire process of addressing climate change via the UNFCCC had been one that followed the "precautionary principle" which essentially directed a Hippocratic approach: first do no harm. The precautionary principle further adheres to an ethos that suggests corrective or stabilizing actions be taken even in the face of incomplete evidence if it appears that those actions are reasonably in line with expected conclusions. The Second Assessment affirmed this direction that had been taken via the UNFCCC and its associated COPs, but was by no means the final word on anthropogenic

[33] Quoted in John R. Justus and Susan R. Fletcher, *Global Climate Change* (Washington, D.C.: Library of Congress, 2004).

influence on climate change. The Third IPCC Assessment Report (TAR) was published in 2001and further refined the SAR; it will be considered in more detail below.

From the first COP which met in Berlin in 1995, the “Berlin Mandate” stated that the commitments of the UNFCCC were “inadequate for meeting the Convention’s objective.”[34] Additionally it exempted non-Annex 1 (lesser developed) countries from further binding obligations for reducing emissions, even though collectively they were expected to be the largest emitters in some 15 years time. Whether it was explicitly realized or not at this point in the negotiations, the first significant wedge was driven into what ostensibly had proved in Rio to be more or less an international consensus to act on climate change, and this wedge would eventually ‘find home’ a few COPs later when the United States began to object to its “differentiated” responsibilities…[35] The Second COP at Geneva in 1996 accepted broadly the IPCC’s Second Assessment of the state of climate change science and the inference that man indeed was a player in global climate change, but the headline-worthy results were those of the Third COP at Kyoto in 1997. It was here that the die was cast for the direction the United States would follow in this process.

The Kyoto Protocol prescribed legally binding emission targets for developed countries – including the United States which would be required to reduce its emissions 7% below 1990 levels by 2012 – but did not include binding commitments for developing countries. While the Kyoto Protocol was signed by President William Clinton in 1998, he did so in defiance of American domestic legislative opinion. The United States Senate – the body that provides its “advice and consent” to the President regarding foreign treaty obligations - passed a resolution that urged him not to sign an agreement without commitments for developing nations; it was a clear example of how pressures applied by domestic constituencies translate to influence U.S. foreign policy. As a result President Clinton never even submitted the Protocol to the Senate, and his successor President George Bush repudiated the agreement altogether in 2001.[36] President Bush’s rejection of the Kyoto Protocol occurred months after the Sixth COP that took place in The Hague

[34] United Nations Framework Convention on Climate Change Secretariat, "A Brief Overview of Decisions," 2006 (accessed April 23, 2006); available from http://unfcc.int/2860.php.
[35] Justus and Fletcher, *Global Climate Change*.
[36] Susan R. Fletcher, *Global Climate Change Treaty: The Kyoto Protocol* (Washington, D.C.: Library of Congress, 1999); Wayne A. Morrissey and John R. Justus, *Global Climate Change* (Washington, D.C.: Library of Congress, 1999).

Netherlands in November 2000. The Fourth COP in Buenos Aires in 1998 and the Fifth in Bonn in 1999 had little substantive advances to show for their efforts after the hullabaloo that had been stirred in Japan; the Sixth COP in The Hague however, was anything but a plodding advancement of a process that had been slowed by the controversy stirred in Kyoto. Differences raged regarding consequences for non-compliance with emission reduction targets, financial assistance mechanisms for lesser-developed nations, and over the proposal by the United States to allow credit for carbon sinks for forests and agricultural land.[37]

Eventually the negotiations at The Hague collapsed and after this contentious gathering, the process – for the United States at least – was broken…by the follow-on "bis" meeting in Bonn in July 2001 that served as a continuation of the Sixth COP, President Bush had rejected Kyoto and the United States delegation did not participate officially in further negotiations. Without the U.S. at the table, the remaining parties reached some significant accords related to clean development mechanisms, carbon sinks, non-compliance and financial assistance that cleared the way for the eventual implementation of Kyoto's goals.[38] After Bonn, the UNFCCC COP met five additional times from 2001 through 2005 at Marrakech, New Delhi, Milan, Buenos Aires, and Montreal. These meetings developed various agreements over Land Use/ Land Use Change and Forestry (LULUCF), carbon sinks and credits, emissions trading, and financial mechanisms such as the Clean Development Mechanism, but from 2000 on the United States has effectively been an observer of the process. [39] An overwhelming number of nations around the world have disagreed with the United States over the Kyoto Protocol; as of April 2006 some "…163 states and regional economic integration organizations have deposited instruments of ratifications, accessions, approvals or acceptances." The United Nations has 191 member states.[40]

Just before President Bush rejected the Kyoto Protocol, the IPCC published its Third Assessment Report (TAR) that incorporated the research that had taken place in the interim five years since its previous issuance of the SAR. This report makes a number of more direct statements about mankind's role with

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[37] Justus and Fletcher, *Global Climate Change*.
[38] Ibid.
[39] United Nations Framework Convention on Climate Change Secretariat, "A Brief Overview of Decisions," (accessed).
[40] United Nations, "Member States," 2006 (accessed April 23, 2006); available from http://www.un.org/members/index.html.

respect to climate change and is the current basis for IPCC projections of *the impact of climate change on peoples and states around the globe*. The IPCC TAR concludes that global average surface temperatures increased during the 20th Century by approximately 0.6 degrees Celsius. The 1990s were considered very likely (with a 90 to 99% probability) the warmest decade of the record and 1998 the warmest year. The TAR further estimates decreases of approximately 10% of snow cover since the late 1960s and reports a "widespread retreat of mountain glaciers in non-polar regions during the 20th century." Northern hemisphere sea-ice is estimated at having decreased between 10 and 15% since the 1950s in extent and by up to 40% in thickness. Globally sea level is estimated as having risen between 0.1 and 0.2 meters, and ocean heat content has "…increased since the late 1950s, the period for which adequate observations of sub-surface ocean temperatures have been available."[41]

The TAR estimated that rainfall increased by 0.5% to 1% per decade in the 20th Century over mid- and high latitudes of the Northern Hemisphere continents, and by some 0.2% to 0.3% over tropical land areas while decreasing some 0.3% per decade in the Northern Hemisphere sub-tropics between 10 degrees and 30 degrees North; the TAR reports insufficient data for such estimates in the Southern Hemisphere. Increases in the frequency of heavy precipitation events in the Northern mid- and high latitudes of between 2 and 4% are estimated over the latter half of the century, with a corresponding 2% increase in cloud cover over these areas that appears to be related to a decrease in daily temperature *range* in these areas. Warm episodes of the El-Nino-Southern Oscillation (ENSO) phenomenon are regarded as "more frequent, persistent and intense since the mid 1970s, compared with previous 100 years." Relatively small areas of global landmasses are assessed to have experienced increased severe droughts or severe wetness; in some parts of Africa and Asia both the frequency and intensity of droughts are estimated to have increased. The IPCC TAR also reports that some areas have *not* warmed in recent decades, including areas of the Southern Ocean and Antarctica, nor were significant trends noted with respect to Antarctic sea ice. Of note, no

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[41] Intergovernmental Panel on Climate Change, *Summary for Policymakers: A Report of Working Group I of the Intergovernmental Panel on Climate Change Third Assessment Report* (Geneva: Intergovernmental Panel on Climate Change, 2001).

conclusions were made about the intensity and frequency of tropical or extra-tropical storms which appeared to be dominated by "inter-decadal to multi-decadal variations" rather than long term trends.[42]

The IPCC's TAR makes some stronger assessments of human intervention in the climate system than did earlier IPCC assessment reports. There is little uncertainty or questioning in the tone of this report: climate change is occurring and man is a participant. Change is ascribed to factors that are both internal to the climate system, and to external factors that include natural and anthropogenic forcing, but there is little doubt that the anthropogenic portion is considered prominent. The TAR estimates that atmospheric CO2 has increased approximately 31% since the onset of the industrial revolution in the 18th century, a concentration it estimates has not been exceeded in over 400,000 years, and possibly not in the last 20 million years. Importantly the *rate* of increase is considered unprecedented for at least the span of the previous 20,000 years. Without specifying what precise percentage of this rise should be ascribed to anthropogenic responsibility, the report implies that most of the detectable increase of atmospheric CO2 is of human origin…and it attributes about three quarters of human emissions to the burning of fossil fuels and the remaining quarter to land use changes. The TAR estimates that about half of the anthropogenic CO2 emissions are sequestered in terrestrial or oceanic sinks, and that variability in the rate of increase in atmospheric concentration over the past two decades is most probably associated with the effect of climate variability from situations such as El Nino on the oceanic and terrestrial processes that take up or release carbon.

Other greenhouse gases like methane follow similar patterns of increase in the timespan since the Industrial Revolution began (though five times as much as CO2!), and present methane concentrations similarly have not been exceeded over a comparable period as was the case for CO2 – almost half a million years! The TAR accredits half of methane emissions to anthropogenic responsibility. The atmospheric concentration of the greenhouse gas nitrous oxide is also reported to have risen, but not as much as carbon dioxide or methane, though it is reported at the highest levels in at least the past thousand years. Other greenhouse gases have differing profiles for concentrations; some indicate diminishing rates of increase and

[42] Ibid.

some a leveling off or even recent decreases that are at least partially explained because of the effects of other international protocols that addressed their production and use. While it is set out in fairly antiseptic prose that is supported by tables and statistics for each of the gases under consideration, in general the TAR strongly ascribes increases in greenhouse gas concentrations to anthropogenic sources, a significant thematic ratcheting up of the dialogue since the FAR and SAR were published. The message to policy makers is clear: the planet is warming and man has at least some responsibility for what is taking place.

Projections of climate change depend on mathematical models that are based on current understanding of the physics and thermodynamics of atmospheric and oceanic processes, upon the initialization of these models by sufficiently sampled data, and upon computational power and the limitations of algorithmic mathematical descriptions of non-linear processes. They are far from perfect and remain an Achilles heel for proponents since nay-sayers that are sufficiently versed in the modeling field can attack model results based on these limitations. In general few critics would not agree that climate models have improved in recent years, however, and the IPCC TAR states that "Confidence in the ability of models to provide useful projections of future climate change has improved due to their demonstrated performance on a range of space and time-scales." Specifically, water vapor, sea ice dynamics, and oceanic heat transport are singled out as having been improved in the models.[43] Importantly, model simulations that utilize estimates of natural and anthropogenic forcings do an admirably descriptive job of simulating the temperature changes observed throughout the twentieth century - a result that when viewed graphically goes a long way to convincing the observer that human causes have much to do with the changes that have been observed in the atmosphere. The TAR leaves no doubt in stating this; while the SAR had posited that evidence suggested a human influence on climate, the TAR arrives at a stronger conclusion: "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."[44]

In the five years since the SAR had been published, gains had been made at "reducing uncertainty, particularly with respect to distinguishing and quantifying the magnitude of [climate] responses to different

[43] Ibid.
[44] Ibid., 10.

external influences." Warming over the previous 100 years was "very unlikely to be due to internal variability alone," and warming over the previous 1000 years "was unusual and unlikely to be entirely natural in origin." Newly applied techniques had determined "detection and attribution studies consistently find evidence for an anthropogenic signal in the climate record of the last 35 to 50 years." Attempts to discern measured responses via *natural* forcings found that they may have contributed to warming, but did not find that these natural forces could account for the entire range of change without the anthropogenic contributions. A synthesis of the studies reviewed by the IPCC for the TAR indicated that "over the last 50 years, the estimated rate and magnitude of warming due to increasing concentrations of greenhouse gases alone are comparable with, or larger than, the observed warming." The end result was that after merging natural and anthropogenic forcings, climate models were capable of ably depicting the warming trend over the period since the Industrial Revolution…an important conclusion that lays the majority of responsibility for the measured warming trend squarely at the feet of anthropogenic sources. "In the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations. Furthermore, it is very likely that the 20th century warming has contributed significantly to the observed sea level rise, through the thermal expansion of sea water and widespread loss of land ice."[45] Significant as scientific conclusions, these statements are important for the *effects* that such environmental changes might have for mankind, and the IPCC TAR went on to leave little doubt that these effects might be anything less than significant.

While the search for signs of anthropogenic responsibility may have been one of the central goals of the IPCC efforts to describe climate change – to inform policy makers that might then presumably act upon this information - forecasting the *effects* or *impact* of climate change on mankind were equally central to this effort. For it is in the manner that climate change affects the patterns of human society that it will receive the attention of governments and leaders…and potentially instigate political action to rectify or at least mitigate some of these effects, if even possible given the incredibly complicated climate system and the lag times between actions and results that are still ill understood. The IPCC TAR therefore went into some detail in ascribing the likelihood that certain environmental changes *had* indeed occurred – for even

[45] Ibid.

measuring parameters on a global scale throughout the atmosphere and oceans is not a simple task - and the probability that they might persist or worsen into the future. Change does not imply an inherent negativity, even from the viewpoint of human society; but the requirement to adapt does imply a level of effort that translates into economic and social ramifications that tend to be a threat at least to the *status quo*. And since many populations around the world are already at risk and lacking the wherewithal to adapt to change, threats to the *status quo* may mean threats to stable economies and lifestyles at a minimum…or perhaps even may prove severe enough to threaten survival of individuals and groups upon failure to adapt.

Focusing on potential future impacts that would directly impinge upon society, the IPCC TAR projected changes in a number of extremes of weather and climate: higher maximums in temperature and hot days over land; higher minimum temperatures with fewer cold days over land; reduced diurnal temperature ranges over land; increase of heat indices over land; intense precipitation events; increased summer continental drying and associated risk of drought; increase in tropical cyclone peak wind intensities; increase in tropical cyclone mean and peak precipitation intensities. The "confidence in observed changes" ranged from likely to very likely (from 66-90% to 90-99%) except for the cases related to tropical cyclones for which there was not enough information to draw strong conclusions. However, the "confidence in projected changes" through the 21st century were deemed almost all "very likely," and the tropical cyclone indices considered "likely." Phenomena such as "greater extremes of drying and heavy rainfall…[which would]…increase the risk of droughts and floods" related to events such as El Nino are expected to be amplified; variability in the duration and strength of monsoon precipitation are projected throughout Asia; disruption of thermohaline circulation in the northern hemisphere is possible, even to the extent that it could be shut down entirely; sea-ice and snow cover are projected to decrease and glaciers and ice caps to continue their retreat; and sea level is projected to rise by up to a meter over the course of 100 years.[46] With each of these scenarios implying varying degrees of impact, uncertainties in rate and amount are overshadowed by the specter of the certainty that change is coming and that human societies – from the most developed to the least developed - are squarely in its path.

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[46] Ibid., 15-16.

For all of the sense of rate, direction, extent, intensity and *responsibility* that the IPCC Third Assessment Report provides with respect to the magnitude, trends, and underlying causes of climate change, there is still an underlying sense of uncertainty. That is not meant to refute any of the statements of the IPCC nor the science behind them. But no matter how solid the reasoning, or painstaking the measurements, or complex the mathematical constructs, nobody really knows how well the most advanced climate models will predict future states, or whether non-linearities of the physical world that science still struggles with will turn forecast conditions on their end. Models verify when they accurately depict past events…but if future events prove dramatically different for reasons not taken into account by the modelers – for any number of reasons, and not because of their lack of expertise – the models may have no legitimate shot at forecasting future states. This sense of uncertainty and dynamic playing field is not at all an unfamiliar pattern for science…and it is a central attraction for scientists. Uncertainty leads to questions, which leads to theories, experimentation, and discovery in an unending pattern that describes the advancement of knowledge. Much of the current state of climate change science owes its foundations to this form of institutional heresy. Without challenges to accepted orthodoxies, climate change would still be considered an incremental process on scales perhaps beyond the influence of anthropogenic forcing. What is more, of late there has been another sea change in the understanding of climate change, a ripple that may not be heretical as much as radical.

While over the last forty years there has been growing evidence that anthropogenic forcing could in fact influence climate dynamics, there has been a sense from both the model outputs and the general discussion of the IPCC Reports that the effects that we are witnessing are part of an *incremental* ratcheting up of global warmth, accepting even if that eventually means that shifting atmospheric and oceanic patterns might eventually lead the system to the counterintuitive effect of cooling some areas while warming others. Ongoing research continually sheds light on climate processes, and with research techniques becoming ever more sensitive to the proxies that reveal the variance of temperature and the constituent gases of paleo atmospheres, another signal has become evident that both elevates concern and frustrates potential efforts to identify solutions. It may be that climate is changing, and that man has an important part in influencing the current trend; but like squeezing the trigger of a gun or applying pressure to a light switch, the resultant

"bang" or sudden illumination might better describe how climate might be altered than a gradual shift towards a warmer (or colder) future. This is not semantic at all, even if the end result is similar; rate of change has everything to do with man's ability to adapt to it. If change occurs quickly – on the scale of a few years as opposed to decades even – the problem may be much direr than even the chicken-est of Chicken Little's might have alarmed. Much remains to be interpreted over whether *abrupt climate change* is more the pattern scientists should be seeking; the clues here stem also from the earlier work where the marine environment and ocean science intersect with security concerns, and understanding of the potential impacts of abrupt climate change may depend as heavily where these central considerations of this current work coincide in the future.

The Barrel of a Gun…Abrupt Triggers of Climate Change

It is appropriate that the work of something of a scientific heretic is a valid starting point for contemplating theories of abrupt climate change. The German meteorologist and sometimes geological theorist Alfred Wegener is just such a personality. Wegener's scientific heresy does not impinge so much on the main story - his central apostasy challenged orthodoxies in the field of geophysics by positing that continents might actually move - but in a satisfying sense of balance considering what his work would eventually lead to in understanding ocean dynamics, it was a group of oceanographers that eventually elevated Wegener from something of a scientific crackpot to visionary when they struck upon a submarine method of demonstrating the likelihood of his tectonic theory. Comparing high resolution bathymetric charts with equally high resolution magnetic charts of the ocean floor (reasons for developing the instruments that collected this data and going to the expense of sending ships to sea to gather it from a naval perspective have already been addressed), the researchers in the mid-1960s showed that crustal spreading centers located at mid-ocean ridges and subduction zones located in submarine trenches supported the theory that the continents indeed moved atop a fluid mantle.[47]

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[47] M. Grant Gross, *Oceanography*, ed. Stephen Helba, Sixth ed., Merrill Earth Science Series (Columbus: Merrill Publishing Company, 1990), 17-30; James H.W. Hain, "Unafraid to Take Risks," *Oceanus* 29, no. 4 (1986): 89.

Unfortunately Alfred Wegener did not live to see this vindication; in fact he died while realizing the efforts for which he is considered in this present account – the first attempts to core into the ice of Greenland to determine what such investigations might tell about the earlier state of the atmosphere. Conducted in brutal conditions in the 1930s, the expedition was an unqualified scientific success. Wegener's partners were able to demonstrate that ice indeed held a record of the past. Exploitation and further exploration of the Greenland ice were interrupted by World War II, but even this conflict demonstrated the importance of Greenland in determining questions of this sort. The icy battleground was fought over as a weather outpost to provide advance warning of westward traveling weather systems over the North Atlantic and Scandinavia. This essentially is the same reason that Greenland is important geographically for climate studies: weather systems generally track west to east and their patterns vary northerly and southerly according to oceanic and atmospheric parameters that are the central features under study. But as Wegener and his partners proved with self-sacrificing dedication to scientific inquiry, the clues to the variability of these phenomena were locked in the frozen ice sheets of the vast island. After World War II, this same territory held interest for the U.S. Army as a weather outpost and for its proximity to the Soviet Union: the array of Distant Early Warning (DEW) sites that the United States emplaced across the frozen north included some facilities in the barren snowfields of Greenland. It was because of this interest - and the proximity to extant American military facilities – that after World War II a scientist at the Army's Snow, Ice and Permafrost Research Center (SIPRE) was able to convince the United States Government that it would be beneficial research to conduct follow-on research to the Wegener Expedition's ice-breaking studies in Greenland. Interest in the coming International Geophysical Year provided the context and the Army subsidized the logistical support necessary to conduct such an undertaking. SIPRE scientists successfully cored the Greenland ice and initiated years of intensive study that would eventually yield important clues for the study of climate.[48]

The procedural device that scientists use to investigate one parameter from the measurement or observation of another is known as a *proxy*. In the 1800s, the naval oceanographer Matthew Maury used the seafloor detritus that had been brought up by the Brooke sounding mechanism to infer that currents on

[48] A more complete account of this accomplishment is detailed in Cox, *Climate Crash: Abrupt Climate Change and What It Means to Our Future*.

the ocean floor were mild if even present; the microscopic analysis of the sounding sample had shown that it consisted of the tiny shells of decomposed plankton that were in remarkably good shape. The absence of sand or gravel and the preservation of the tiny delicate shells convinced Maury that the seafloor was not abraded by the action of currents…and hence a safe repository for the Atlantic Cable.[49] The evidence of planktonic life in seafloor sediments is also used by oceanographers as a proxy for climatic conditions in the ocean. The presence or absence of specific types of shells – calcareous or siliceous – provides information about the types of sea life were present at a given time, and something about the temperature and chemical composition of the waters (and atmosphere in contact with those waters) from what scientists know of the tolerances that these creatures have for such parameters. Other techniques that detect the presence of various isotopes such as carbon and oxygen can also infer something about the atmospheric and oceanic conditions at the time these creatures were alive, as well as date the sediment in which they are found.[50]

Chemical constituent and isotopic analysis are essential proxies for scientists in studying the oceans and in slightly different fashion are essentially the same method that atmospheric scientists use to study the ice that has been painstakingly cored from the Greenland ice sheet and other areas such as Alaska, Siberia, Antarctica, and various glacial sheets around the world. From the layers visible in the ice (visual stratigraphy), scientists can detect and say something about annual snowfall; from the dusts and pollens they can infer parameters of aridity, wind strength and direction, and temperature; from isotopic analysis of oxygen in snow and ice they can infer something about the temperature when precipitation occurred; and from the tiny bubbles of ancient air that are locked in the interstices of the ice they can actually sample these paleoatmospheres to determine their constituent gaseous makeup. The ice cores are truly a window into past climates, a window that when first thrown open altered considerably the views on climate change.[51]

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[49] Maury, *The Physical Geography of the Sea*.
[50] Anikouchine and Sternberg, *The World Ocean*, 92-118; Francis P. Shepard, *The Earth Beneath the Sea* (New York: Atheneum, 1967), 241-265.
[51] Cox, *Climate Crash: Abrupt Climate Change and What It Means to Our Future*, 47-52; Kendrick Taylor, "Rapid Climate Change," *American Scientist* 87, no. 4 (1999).

Environmental climatologies reveal something about averages, baselines from which daily temperature or other parameters vary but which provide some notion of a mean that can be expected to prevail. Depending on how long time series datasets are sampled, climatologies may demonstrate ranges of parametric variance from millennial (and longer epochs) to centennial down to annual and seasonal variance, or in some cases may be broken down even further. As described in the previous case, Maury's Wind and Current Charts were essentially graphical climatologies, with individual tracks of ships color coded by season and further identified to the month of the voyage by the type of solid, dotted, or broken line. With enough information added over time as he collected logbooks from those who used his data, Maury's Wind and Current Charts eventually became Pilot Charts with graphical representations of the monthly means of surface winds and currents; in this presentation they provided a mariner with a visual depiction of statistical expectancy – a sense that on a given voyage certain prevailing conditions would most likely be encountered. Climatologies of this sort imply that a long-term mean exists and that weather simply varies around it.

The difficulty for climatological analysis comes when the mean becomes a moving target…expected variance occurs over wider ranges since the baseline is not stationary, and the chart becomes of little utility. At some point a new climatological baseline must be established for statistical variance to be of any use; to be of *practical* use, climatologies must be based upon time scales that humans find useful to their endeavors. Climate *change* becomes an issue when these expected baselines – these relatively constant average conditions - are observed to shift as variance begins to exceed expected ranges above or below the mean. Climate study developed as a scientific interest from the Victorian-era investigations conducted by geologists and geophysicists in Europe and America and from the realizations that over the course of millennia the Earth moved between periods of warmth and extreme cold. When it became evident that ice sheets and glaciers advanced, persisted, and eventually retreated on these long time scales, the notion of global climate shifts became conjoined with the same plodding incremental sense that these scientists held for the geologic and geophysical processes that they studied. Since the period of human history is

practically a rounding error when compared to the extent of these glacial and interglacial cycles, there was a sense that shifts between periods of warm and cold were too slow for humans to be impacted.[52]

Early work by the Serbian astronomer Milankovitch led to the pairing of climate states with planetary orbital variables of tilt, precession, and eccentricity as the Earth moved around the sun; the timescales with which these variables influenced ice ages was 40,000 years, 20,000 years and 100,000 years respectively. While Milankovitch's theory was in dispute for decades, it fit with the rather long-term sense of climate extremes such as ice ages in general. Scientists studying climate proxies in ocean sediments eventually corroborated Milankovitch's theories to the point that they gained credence and became the touchstone from which other changes in climate would be measured.[53] Since the Milankovitch cycles did not account for *all* variations in the geologic record, it was expected that other process were at work. But the idea that something as ponderous as global climate, with its intrinsic scales and the thermal inertia of the ocean if not the atmosphere, could shift in as dramatic a fashion as it did between glacial and interglacial periods on shorter timescales than the millennia of Milankovitch – perhaps even human timeframes rather than geologic ones – was a little more difficult to visualize. A recent Hollywood attempt to dramatize the human understanding of such a rapid event so sped up the processes as to make the theory almost farcical.[54] But from the cold trenches of the ice research stations in Greenland and elsewhere, a signature of climate change began to emerge that occurred over scales that were much more rapid than 18th through early 20th century scientists would have believed possible.

With more exact sampling techniques that relied on electro-conductivity, mass spectroscopy, and other advanced scientific investigatory methodologies, scientists teased climate information from ice cores revealing that dramatic climate swings had occurred even in the midst of glacial or interglacial periods (interstadial change) that had long been perceived as periods of relative climatic calm. With greater accuracy and additional proxy links to corroborate the historical record, an ever more refined picture of

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[52] Cox, *Climate Crash: Abrupt Climate Change and What It Means to Our Future*, 20-24.
[53] Richard B. Alley and Michael L. Bender, "Greenland Ice Cores: Frozen in Time," *Scientific American* February (1998): 80-81.
[54] Andrew J. Weaver and C. Hillaire-Marcel, "Global Warming and the Next Ice Age," *Science* 304, no. 5669 (2004).

climate extremes emerged from the ice cores. Because snow layers were laid down annually in the areas where the cores were drilled and remained relatively undisturbed (except at depth because of complicated ice flow dynamics), the ice records were more complete than ocean sediment records since they were less subject to processes that might blur their structure such as ocean currents or bioturbation. The ice record revealed significant variations in climate that occurred not only over tens of thousands of years, but on much shorter scales of hundreds of years, even down to decadal and shorter timeframes. With techniques that allowed precise dating of the more recent record, climate phenomena emerged that were quickly recognized as coincident with events that took place in human history…phenomena that might have proved extreme enough to *influence* the course of human history.

The present epoch in the Ice Age continuum is known as the Holocene, an interglacial period of relative warmth that extends back some 12,000 years. Most of what we know of human history was recorded in this timeframe. As events from the societal record were overlain with the climate information emerging from the Greenland ice cores, a sobering picture was revealed. Climate changes appeared to track closely with important human happenings: the foundation and disintegration of civilizations, migrations, droughts, famines… With ever more refinement of the climatological record there were additional links to the historical record. The ironic naming of Greenland and Iceland may have had more sensible basis than the legendary subterfuge accredited to the discoverer of the larger island in order to attract inhabitants by virtue of its alluring name. As the ice-core record appears to corroborate, Greenland had a much more temperate climate around the time of its settlement in A.D. 850 that lasted some 500 years and became known as the Medieval Warm Period. After that time, however, came a period known as the “Little Ice Age” that lasted some 400-500 years until the mid-1800s. The changes that this relatively sudden shift (in geologic time) caused were apparently too much for the Greenlanders who migrated south on their island and eventually disappeared altogether from their settlements in little over 100 years. Similar climatic shifts that can be coaxed from the record appear to correlate with the growth and waning of other civilizations and peoples as far-flung as Babylon, the Yucatan, Egypt, the American Southwest, India and Peru.[55]

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[55] Richard B. Alley, "Abrupt Climate Change," *Scientific American* November (2004); Cox, *Climate Crash: Abrupt Climate Change and What It Means to Our Future;* Peter B. deMenocal, "Cultural Responses to Climate Change During the Late Holocene," *Science* 292, no. 5517 (2001); Brian Fagan,

In some instances significant interstadial climatic change appears to have been exacerbated by even shorter spikes similar to those that are evident today in events such as El Nino events which sporadically affect climate patterns across the Pacific and that scientists theorize reach even further across the planet from source regions through atmospheric and oceanic "teleconnections."[56] As paleoclimatologists work with archaeologists and paleographers, closer and more significant links are being discovered that indicate strong relationships between climatic and social change. These linkages infer in some instances that the ultimate survival of the societies was at stake, while in others to some lesser extent perhaps at least the integrity of their economic and social structures; in either context however, their environmental security hung in the balance.

While the goal of the research on the ice fields of Greenland was to investigate climate change, the fidelity of the data that the scientists encountered revealed greater small-scale fluctuations in the climatic record than they had expected to see. At first these perplexing variations were thought to be "noise" in the data, for instead of gradual cooling or warming during transition periods from glacial to interglacial temperatures, there were rapid fluctuations that bucked the trend throughout the record. Searching for a clear signal was the goal, "…the ability to find order where others see only chaos." But perhaps the signal *was* in the variations of the record… It took some time for scientists to believe their data because "…the idea that *the chaos is the signal* flies in the face" of the habits of scientific inquiry.[57] Comparing the ice core data with glacial data, scientists identified 24 periods of abrupt change that occurred *during* the last ice age interstadial. Rapid warming events were recorded before gradual and then quick returns to colder periods. "The sharp, erratic changes seemed to show a climate that was shifting in and out of two distinct modes of operation…." What was more, these climatic spikes could be correlated to other signals from the

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Floods, Famines, and Emperors (New York: Basic Books, 1999); H. Weiss, M. Courty, W. Wetterstrom, F. Guichard, L. Senior, R. Meadow, and A. Curnow, "The Genesis and Collapse of Third Millenium North Mesopotamian Civilization," *Science* 261, no. 5124 (1993).

56 Alley, "Abrupt Climate Change."; Peter U. Clark, Nicklas G. Pisias, Thomas F. Stocker, and Andrew J. Weaver, "The Role of Thermohaline Circulation in Abrupt Climate Change," *Science* 415, no. 6874 (2002); Cox, *Climate Crash: Abrupt Climate Change and What It Means to Our Future*, 84-85; Jean Lynch-Stieglitz, "Hemispheric Asynchrony of Abrupt Climate Change," *Science* 304, no. 5679 (2004); F. Sirocko, D. Garbe-Schonberg, A. McIntyre, and B. Molfino, "Teleconnections Between the Subtropical Monsoons and High-Latitude Climates During the Last Deglaciation," *Science* 272, no. 5261 (1996).

57 Cox, *Climate Crash: Abrupt Climate Change and What It Means to Our Future*, 54.

paleo record…*oceanic* events signaled by "…advances and retreats of cold polar water in the North Atlantic Ocean."[58]

The geochemist Wallace Broecker took this evidence to a further conclusion: perhaps these advances and retreats of polar water masses and correlated atmospheric changes *required* fundamental changes in the "…the operation of the ocean…a turning on and off of deep water formation in the northern Atlantic?"[59] Broecker built on the earlier work of oceanographer Henry Stommel who had proposed that the oceans operated in different states during glacial and interglacial periods. Broecker theorized a complex pattern of thermohaline circulation that depended upon the sinking of cold saline waters in source regions and replacement by warmer surface waters that were in effect pulled from the tropics. Demonstrating how these flows were linked globally, he described an "Ocean Conveyor" that was responsible for both a turnover of ocean waters and transport of heat from tropical to polar regions.[60]

Broecker's graphical version of his ocean circulation model – by his own estimate a gross oversimplification - became a frequent diagram in oceanographic papers and interpretive discussions in the popular press. Had it not predated Broecker's work, even the cartoonish diagram used by the diabolical THRUSH scientist in *The Man from U.N.C.L.E.* might have been derived loosely from the graphical representation. The gross features of Broecker's conveyor demonstrate the criticality of stable oceanic flow to current climatic conditions; without the looping circulation to carry warmth northwards, the climates of certain continental areas such as Europe might prove altogether different. It was not merely a philosophical question to ponder… As scientists investigated the record, ever more sudden and extreme changes emerged; if these past events might be replicated, extreme changes might be in store - changes that could take place on the order of years to decades, and not of centuries or millennia.[61] If man was influencing

[58] Ibid., 99; Jeffrey P. Severinghaus and Edward J. Brook, "Abrupt Climate Change at the End of the Last Glacial Period Inferred from Trapped Air in Polar Ice," *Science* 286, no. 5441 (1999).
[59] Cox, *Climate Crash: Abrupt Climate Change and What It Means to Our Future*, 103.
[60] Wallace S. Broecker, "Thermohaline Circulation, the Achilles Heel of Our Climate System: Will Man-Made CO2 Upset the Current Balance?," *Science* 278, no. 5343 (1997); Cox, *Climate Crash: Abrupt Climate Change and What It Means to Our Future*, 104.
[61] Wally S. Broecker and Sidney Hemming, "Climate Swings Come into Focus," *Science* 294, no. 5550 (2001); Clark, Pisias, Stocker, and Weaver, "The Role of Thermohaline Circulation in Abrupt Climate

climate, driving it towards one of these abrupt changes, he was doing so at his own peril. Broecker described the danger, “We play Russian roulette with climate, hoping the future will hold no unpleasant surprises. No one knows what lies in the active chamber of the gun, but I am less optimistic about the contents than many.”[62]

The mechanics of disrupting thermohaline circulation in the oceans remains a matter of investigation in the present day. The paleo records from ice data and ocean sediment cores provided the insight into the potential, but not the exact mechanics of the triggers, although they too are theorized from events in the record. One leading theory for one of the earlier Atlantic Conveyor alterations was that a large continental lake that covered southern Canada and the Northern United States near the Great Lakes was partially drained when the Laurentide ice sheet melted enough to provide a path via the St. Lawrence River or the Hudson Strait, providing a large lens of fresh water that overlay the warmer saline waters transported north by the Gulf Stream preventing their cooling and sinking at source regions of downwelling.[63] While this sort of catastrophic event may not be repeated anytime soon, other less alluvial possibilities exist, including significantly altered patterns of rainfall, or melting of polar ice to the extent that a similar lens of fresh water might be created near the ice edge where the Gulf Stream delivers its burthen. Coupled with other changes – such as shifts in the North Atlantic Oscillation of high and low pressure between the Azores and Iceland with corresponding changes in winds and wind-driven ocean current patterns - the cooling, evaporation, and downward mixing of surface waters that occurs in this region could be disrupted in similar – if not identical – fashion as what may have taken place when Lake Aggasiz was drained millennia ago.[64]

Change."; Severinghaus and Brook, "Abrupt Climate Change at the End of the Last Glacial Period Inferred from Trapped Air in Polar Ice."

[62] Quoted in Cox, *Climate Crash: Abrupt Climate Change and What It Means to Our Future*, 110.

[63] D.C. Barber, A. Dyke, C. Hillaire-Marcel, A.E. Jennings, J.T. Andrews, M.W. Kerwin, G. Bilodeau, R. McNeely, J. Southon, M.D. Morehead, and J.-M. Gagnon, "Forcing of the Cold Event of 8200 Years Ago by Catastrophic Drainage of Laurentide Lakes," *Nature* 400, no. 6742 (1999); W. S. Broecker, "Does the Trigger for Abrupt Climate Change Reside in the Ocean or in the Atmosphere?," *Science* 300, no. 5625 (2003); Peter U. Clark, Shawn J. Marshall, Gerry Clarke, Steven W. Hostetler, Joseph M. Licciardi, and James T. Teller, "Freshwater Forcing of Abrupt Climate Change During the Last Glaciation," *Science* 293, no. 5528 (2001); Gerry Clarke, David Leverington, James Teller, and Arthur Dyke, "Superlakes, Megafloods, and Abrupt Climate Change," *Science* 301, no. 5635 (2003).

[64] Laurence Lippsett, "Beyond El Nino," *Scientific American* 11, no. 1 (2000); Stefan Rahmstorf, "Ocean Circulation and Climate During the Past 120,000 Years," *Nature* 419, no. 6903 (2002).

That is something of the conundrum faced by modern climate scientists – determining what other triggers might catalyze events that are equally disruptive, but not initiated by such clear signals as what amounted to a dam bursting in effect. Systematic observations over such large areas are daunting, especially when satellites that provide more or less synoptic coverage are less effective at describing conditions to depth except in a few cases where ocean height as measured by altimeters or sea surface temperatures as measured by radiometers can be extrapolated to infer structure below the surface based upon earlier empirical measurements and mathematical modeling. Measuring salinity however – a critical and fundamental parameter for investigating thermohaline circulation – is an *in situ* process that is both expensive and suffers from the sampling frequency that can miss important features. Research in the field indicates that very small features known as salt fingers are essential to the process of mixing and these are easily missed by a sampling plan even of relatively fine resolution.[65]

For all the effort that might be expended via time- and financially intensive efforts, the ill-defined signal of a climate trigger may elude researchers until other signs indicate that the inertia of the ocean-atmosphere climate system has been levered in another direction. Despite the enormity of the findings emerging from the study of paleoclimates and the inferences for future abrupt climate changes to take place – as well a flurry of articles published in scientific journals for the benefit of climate research peers and to garner additional funding (!) – the story was one that was known to a relatively small circle of researchers. The *Journal of Geophysical Research* is *not* on newsstands everywhere, and even scientific journals that are more widely read such as *Science* and *Nature* have some political overtones that make their stories suspect in some policy circles. But if action on abrupt climate change or support for additional research was to materialize, it would happen only if policy makers and funding agencies knew about it. The United States National Academy of Sciences (NAS) decided that this cutting edge research on abrupt climate change should be exposed to a wider audience….

"Recent scientific evidence shows that major and widespread climate changes have occurred with startling speed. For example, roughly half the north Atlantic warming since the last ice age was achieved

[65] Raymond W. Schmitt, "The Ocean's Salt Fingers," *Scientific American* 272, no. 5 (1995).

in only a decade, and it was accompanied by significant climatic changes across most of the globe."[66] Whether it intended to elevate specifically these elements above the many others involved in this complex arena of atmospheric, oceanic, hydrologic, geologic, biologic, and cryologic uncertainty, in its prefatory statement to its landmark report on abrupt climate change, the National Research Council (NRC) of the NAS highlighted items very germane to this present dissertation. The 2002 NRC study itself was initiated to examine to relatively recent understanding of *abrupt* climate change – as opposed to incremental warming which dominated the paradigm for some four decades and has been the central theme of international efforts including those that drive the negotiations behind the UNFCCC and that have been the basis for most of the review and analysis conducted by the IPCC – but the selection of North Atlantic Ocean temperature as the first parameter of note foreshadows the central role of the oceans in abrupt climate change scenarios. What is more – especially from a security perspective – is the further correlation of the ocean parameter with *significant climatic changes* elsewhere on the planet via earlier discussed mechanisms of teleconnection, changes that hold enormous portent for mankind. "Similar events, including local warmings as large as 16C, occurred repeatedly during the slide into and climb out of the last ice age climate jumps. Severe droughts and other regional climate events during the current warm period have shown similar tendencies of abrupt onset and great persistence, often with adverse effects on societies."[67]

The NRC's abrupt climate change study extended earlier assessments that it sponsored that focused on incremental change more akin to the lines of thinking within the IPCC reports, but now emphasizing the greater understanding of the variability of the processes and the potential for rapid shifts from one state to another. The NRC Ocean Studies Board's 1994 review of oceanographic science's contributions to understanding global climate change indicated an awareness that the scope of change might be important on scales other than global, as well as the impact that climate variability might demonstrate on elements of the nascent post-war concept of environmental security, "Global – or even regional – climate shifts will have far-reaching implications for world economics, energy utilization, national defense, and the health of

[66] National Research Council Committee on Abrupt Climate Change, *Abrupt Climate Change: Inevitable Surprises* (Washington, D.C.: National Academy Press, 2002), 1.
[67] Ibid.

terrestrial and marine ecosystems."[68] But this 1994 OSB report also reveals in retrospect how recently an understanding for *abrupt* climate change has emerged from the data. While describing in detail the various oceanographic programs that sampled the oceans and supplied data for climate models, despite linking numerous oceanic parameters related to climate cycles and carbon balances that affected atmospheric concentrations of carbon dioxide, there is no apparent realization of the critical ocean signal that more recently assumed a focal position among theories of abrupt climate change: changes in thermohaline circulation of the North Atlantic Ocean. The 1994 OSB study was undertaken shortly after the UNFCCC was signed; the ocean was still considered within climate constructs more for its inertial dampening qualities, as a heat source and sink that moderated local extremes of weather and that also held potential for mitigating atmospheric carbon transgressions through various methods of physical, biological and chemical carbon uptake.[69] In both research and abrupt climate change, what a difference a decade can make.

"Technically, an abrupt climate change occurs when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause. Chaotic processes in the climate system may allow the cause of such an abrupt change to be undetectably small."[70] Summarizing the discoveries of paleoclimatologists who had been examining ice core data and ocean sediment records, the NRC report sought to indicate how this new view of climate should be understood by policy makers and the public, especially how it related to the more well known aspects of incremental climate change that had centered the public dialogue, "Abrupt climate changes were especially common when the climate system was being forced to change rapidly. Thus greenhouse warming and other human alterations of the earth system may increase the possibility of large, abrupt, and unwelcome regional or global events."[71] If earlier estimates of incremental climate change provided a way to procrastinate or to rely on technology to bridge the gap to future climate conditions, the prospects for confidently addressing change appear somewhat diminished.

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[68] National Research Council Ocean Studies Board, *The Ocean's Role in Global Change: Progress of Major Research Programs* (Washington, D.C.: National Academy Press, 1994), 1.
[69] Paul C. Stern, Oran R. Young, and Daniel Druckman, eds., *Global Environmental Change: Understanding the Human Dimension* (Washington, D.C.: National Academy Press, 1992), 106, 110.
[70] National Research Council Committee on Abrupt Climate Change, *Abrupt Climate Change: Inevitable Surprises*, 14.
[71] Ibid., 1.

The field becomes once again a question of resiliency in the face of change, but this time much more rapid change with less luxury for "wait and see" strategies or technological innovation apace with climate creep; the societal effects of rapid climate change noted in the NRC report are not so different in specific impacts as those detailed by reports such as the IPCC TAR – although the range of environmental swings and consequent impacts as revealed in the paleoclimatic record indicates more extremes - as they are in the rate at which those impacts would be felt and need to be addressed. Critically the NRC report summarizes not what models *portend* for future climate or specific effects as much as what *evidence* shows from the historical record is possible with respect to future states. What is more, the range of the variables such as temperature and precipitation observed in the historical record – dependent of course on correct interpretation of proxies, but that were cross-correlated by numerous proxy records – and the time scales over which they changed infers that climate *will* behave in a manner such that mankind might not be able to adapt smoothly. The report makes clear that much remains to be accomplished in the matter of forecasting future climate conditions, but revelation about what previously occurred is sobering stuff.[72]

Likely anticipating avenues of attack from vested domestic interest groups, challenges to model predictive capability were preemptively addressed by the NRC, but in a fashion that left open the potential for even more dire effects rather than assuming a defensive crouch for possibly overestimating possibilities, "The abrupt changes of the past are not fully explained yet, and climate models typically underestimate the size, speed, and extent of those changes. Hence, future abrupt changes cannot be predicted with confidence, and climate surprises are to be expected."[73] If the future remained a mystery, little predictive comfort came from a reading of past records: paleoclimatic forcings indicated that little warning might be available before an abrupt shift occurred. Dramatic events such as the flooding of the North Atlantic by the draining of a freshwater body such as Lake Aggasiz were only one possibility for interrupting one pattern and instigating a shift to a new one; stochastic (random) forcing by *natural variability* within a system that

[72] See also Daniel P. Schrag and Richard B. Alley, "Ancient Lessons for Our Future Climate," *Science* 306, no. 5697 (2004).
[73] National Research Council Committee on Abrupt Climate Change, *Abrupt Climate Change: Inevitable Surprises*, 1; National Research Council Panel on Climate Change Feedbacks, *Understanding Climate Change Feedbacks* (Washington, D.C.: National Academy Press, 2003), 54. See also Clark, Pisias, Stocker, and Weaver, "The Role of Thermohaline Circulation in Abrupt Climate Change."

was already at unstable equilibrium was deemed *just as possible* a trigger as more spectacular events that, however unlikely, are perhaps more intuitive and acceptable as reasons for abrupt climate change to occur.[74]

If the phenomenon of Global Warming - or the more accurately descriptive Global Climate Change – made its appearance on the international stage as an atmospheric signal, the field of abrupt climate change is one with a decidedly more oceanic tone. The evidence of rising atmospheric carbon dioxide concentrations as depicted in the Keeling Curve of the Mauna Loa research was the wedge to future research on climate change; with more readily measurable parameters and more appreciable timescales, atmospheric change is easier for humans to grasp. The oceans are perceived as much more steady features – the great moderators of continental climates…reservoirs or sinks of remarkable buffering capacity for heat and for water, and for climate-sensitive elements such as carbon. The potential for oceanic change is entirely within human understanding…but *rapid* change is not so easily envisioned of a fluid body that typically varies on scales orders of magnitude more slowly than atmospheric variations.

The 2002 NRC report *Abrupt Climate Change: Inevitable Surprises* addressed the need for more in-depth understanding of oceanic processes to better resolve the potential for abrupt climate changes to be triggered by changes in its structure and circulation. In its recommendations for key research the NRC report highlighted oceanic circulation and sea-ice process, especially where they related to deepwater formation; land-ice behavior, including storage, runoff, and permafrost changes; and modes of atmospheric behavior and how they change over time.[75] Certainly atmospheric research was already providing much information about changing climate, but with views towards understanding abrupt change, the NRC emphasized that geophysical research needed to focus more on "aspects of the climate system that are believed to have participated in past abrupt changes or that are likely to exhibit abrupt and persistent changes when thresholds are crossed." In the NRC's view this meant research on "modes of coupled

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[74] National Research Council Committee on Abrupt Climate Change, *Abrupt Climate Change: Inevitable Surprises*, 76.
[75] Ibid., 3.

atmosphere-ocean behavior, oceanic deepwater processes, hydrology and ice."[76] Interestingly enough, these were also parameters that long interested naval oceanographers in addressing environmental impacts on naval operations, especially anti-submarine warfare. The NRC report did not state this outright, but in lamenting the termination of certain data sets – under ice records from submarines, central ocean hydrologic sampling stations from weather ships – it indirectly acknowledged their significance.

Additional oceanographic datasets were also emphasized in the report for their importance in resolving abrupt climate change and its triggers: altimetric measurements of ice sheets and ice edge areas, and observations of surface and deep ocean currents. Both of these are also naval datasets, but in a time when open ocean naval operations are giving ground to littoral battlefields, less emphasis means less effort. Ironically without an adversary such as the Soviet Union, there is less immediate naval emphasis in gathering this important data, and despite greater present day civilian oceanographic data collection efforts there are actually fewer datasets and reduced three-dimensional *in situ* observations (four-dimensional if fixed sites are included) than were available during the Cold War.[77]

Abrupt Climate Change: Inevitable Surprises was not meant to alarm policy makers, but to make them aware that complacency with potential for incremental change as heralded by most of the climate change dialogue was potentially a disastrous stance. The report emphasized efforts at capacity and institution building as measures to increase societal ability to address change if it should come in more rapid a fashion than anticipated, and over a wider range of variability than reasonably expected by the more conservative estimates of the mainstream effort. In fact the report espoused optimism that change could be handled by technologically adept societies if they were prepared, and were at the same time ready to extend that preparation to less endowed societies not as capable of adapting to climate change – either sudden or incremental. It also offered a warning that implied that action may be as much in the self interest of technologically advanced countries like the United States (after all, the focus of the NRC report) as it may prove of broader service. "With growing globalization, adverse impacts – although likely to vary from region to region because exposure and sensitivity will vary – are likely to spill across national boundaries,

[76] Ibid., 2.
[77] Ibid., 156-157; Pittenger and Gagosian, "Global Warming Could Have a Chilling Effect on the Military."

through human and biotic migration, economic shocks, and political aftershocks." Without intentionally using the nascent framework of environmental security, the NRC report nevertheless pointed out the relevance of abrupt climate change to many of the elements of the field. "Thus, even though this report focuses primarily on the United States, the issues are global and it will be important to give attention to the issues faced by poorer countries that are likely to be especially vulnerable to the social and economic interests of abrupt climate change." [78]

As with any challenge, the NRC also pointed out that there was opportunity, "The United States is uniquely positioned to provide both scientific and financial leadership, and to work collaboratively with scientists around the world, to gain better understanding of the global impacts of abrupt climate change as well as reducing the vulnerability and increasing the adaptation in countries that are particularly vulnerable to these changes."[79] The question that remained – and remains - is whether the United States would engage the challenge of abrupt climate change as an academic and perhaps humanitarian one, or one that impinged on its national security. As a matter of domestic debate within the United States where public policy can shift as quickly as public opinion, that is as complex and chaotic an issue as is the science of abrupt climate change.

Finding a Voice at Davos…Reaching Out About Abrupt Climate Change

"We have two causes in operation which we may safely assume are among those concerned in producing the Gulf Stream…. One of these is the increased saltiness of its water…and the other is in the diminished quantum of salt which the Baltic and the Northern Seas contain. In one set of these sea-basins the water is heavy; in the other it is light. Between them the ocean intervenes; but water is bound to seek and to maintain its level; and here, therefore we unmask one of the agents concerned in causing the Gulf Stream."[80] For his efforts to describe one of the ocean mysteries of his time, Matthew Fontaine Maury was celebrated in public, but pilloried by scientists - likely as much out of personal and professional animosity

[78] National Research Council Committee on Abrupt Climate Change, *Abrupt Climate Change: Inevitable Surprises*, 156-157.
[79] Ibid., 167.
[80] Maury, *The Physical Geography of the Sea*, 38.

as for his lesser emphasis on earlier theories such as that by another American scientist, William Ferrel, who postulated that the force of winds and the rotation of the earth had much to do with ocean circulation.[81] Modern day oceanographers *do* credit winds and planetary motion (as well as bathymetric constraints) more so than haline differences in explaining the motion of currents such as the Gulf Stream, but this aspect of ocean circulation – combined with temperature effects to more fully capture the emphasis on *density* and collectively known as thermohaline circulation (THC) – has become a (if not *the*) central focus of the investigations into oceanic involvement with climate.

As the lynchpin of the Global Conveyor of ocean currents responsible for much of the oceanic heat transport through the oceans, the operation or shutdown of THC in the North Atlantic is now the subject of considerable oceanographic interest and inquiry. Because of the aforementioned difficulties in sampling salinity, however, awareness of the issue does not translate to ready or widespread availability of data to investigate the phenomenon. A study published in *Nature* in 2002 painstakingly reconstructed what information was available to create a limited long time series of hydrographic data in the North Atlantic. The authors highlighted the importance of the region, "The Labrador Sea is a critical location for the Earth's climate system. In its upper and intermediate layers, annual to decadal variations in the production, character and thickness of its convectively formed mode water directly determine the rate of the main Atlantic gyre circulation. Through its deeper layers pass all of the deep and bottom waters that collectively form and drive the abyssal limb of the Atlantic meridional overturning circulation. Around its margins pass the two main freshwater flows from the Arctic Ocean to the North Atlantic that have been implicated in model experiments with a slowdown or shutdown of the meridional overturning circulation."[82] The Labrador Sea - at the vertex of the Cold War GIUK Gap - was ground zero for the effects that oceanographers considered critical to driving the Global Conveyor by means of mixing that depended upon a delicate density balance; that balance hinged on the temperature and salinity of the water masses that intermingled along the southern flank of Greenland, and the *Nature* article reported that in both

[81] Steve Ritchie, "As It Was," *Hydro International* 1, no. 2 (1997); Williams, *Matthew Fontaine Maury: Scientist of the Sea*.
[82] Bob Dickson, Igor Yashayaev, Jens Meincke, Bill Turrell, Stephen Dye, and Juergen Holfort, "Rapid Freshening of the Deep North Atlantic Ocean Over the Past Four Decades," *Nature* 416, no. 6883 (2002).

intermediate and deep flows over the course of the previous four decades there was both sustained and widespread freshening.

The World Economic Forum that meets annually at Davos, Switzerland is "an independent international organization committed to improving the state of the world by engaging leaders in partnerships to shape global, regional and industry agendas."[83] With theories of abrupt climate change becoming more widely known among climate scientists, notions that societies might adapt under the more mainstream theory that climate change was a slow steady progression to a warmer future were in question. How might scenarios differ if change was in fact, sudden? The Director of the Woods Hole Oceanographic Institution, Dr. Bob Gagosian was invited to Davos to address this question in a session on abrupt climate change. Not long after the publication in *Nature* described the freshening of the North Atlantic, Dr. Gagosian tackled the issue directly with a series of questions and answers related to present understanding of the issue, the first of which was the title of his presentation, "Should We Be Worried?"

For an audience that had likely considered scenarios of climate change as sketched by the IPCC Reports, Dr. Gagosian set out to explain how *abrupt* theories of climate change differed, including the potential for climate shifts that took place on the order of a decade or less, and that - counterintuitive to a scenario of global warming - might produce substantial *regional* effects, and *colder* climates. He pointed out that while theories of abrupt change were established in certain circles, they were not known among "the wider community of scientists, economists, policy makers, and world and political leaders." Dr. Gagosian cautioned that these individuals might "be planning for climate scenarios of global warming that are opposite to what might actually occur." He emphasized that the timing of change would also prove critical: shifts that took place in the near future might be different than those that occurred a century after greenhouse warming continued to warm the planet. He went on to describe the climate discoveries that grew from research on the Greenland ice and were brought to flower by their connection to changes in ocean circulation and what that heralded for potential futures. Indicating that ocean conveyor mechanics were responsible for a large percentage of the Gulf Stream transport of warm waters to areas where they

[83] World Economic Forum, "About the World Economic Forum: Entrepeneurship in the Global Public Interest," 2006 (accessed May 29, 2006); available from http://www.weforum.org/.

warmed the European continent (if only Maury was present to hear it!), he cautioned that this was responsible for up to 5 degrees Celsius of present warmth when averaged annually and made for winters altogether different than they would be without maritime influence. Loss or partial shutdown of this Conveyor portended temperatures from 3 to 5 degrees Celsius cooler and winters twice as cold as the worst on record. What is more, effects in all likelihood would not be limited to Europe; through teleconnections ancient shutdowns of the Ocean Conveyor were linked to widespread drought conditions around the world – areas already on the margins of sustainability and ill-prepared to be rocked by further pressures.[84]

To an audience full of businessmen and politicians, Gagosian committed what some consider a sin in giving a scientific talk to non-scientists: he showed data - the graphs that had been published in *Nature* depicting the freshening of North Atlantic waters in the area around the Labrador Sea. While his listeners might not have understood the abscissal or ordinal values, they could discern a trend…and that trend was worrisome in the context of a potential trigger for initiating an abrupt change in climate for a world already ill-prepared for a gradual one. Freshening of the surface waters of the Labrador sea might fix a cold cap on the warm waters that helped to moderate the European climate, and through disrupting patterns of density might slow or halt the Conveyor altogether…in a matter of *years*. Laying the scientific cards on the table – and as any institution director might, possibly angling for funding – Dr. Gagosian then indicated that scientists did not know when such a scenario might occur, nor about many of the critical parameters including fresh water contributions that figured into the equation. Deep ocean measurements were sorely wanting, and with the end of the Cold War many of the long time series hydrographic sampling efforts that had been directed at anti-submarine warfare had been eliminated. Satellite remote sensing was limited in its effectiveness in revealing the critical parameters necessary to resolve THC changes, and an incipient effort to measure parameters *in situ* via a series of drifting buoys was constrained by funding and incapable of gathering important *deep* data. Information about the global hydrological cycle was also very much needed for its effect on a system that depended on variations in fresh water additions to saline currents.[85]

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[84] Robert B. Gagosian, "Abrupt Climate Change: Should We Be Worried?," 2003 (accessed May 15, 2006); available from www.whoi.edu/adminstration/president/news_030127.htm.
[85] Ibid. (accessed).

Lest his audience consider his discussion more abstract projections of the sort that had been heard – and widely ignored - before, Gagosian next reviewed for them the relatively recent evidence that paleoclimatologists had linked to events that they might better appreciate: the Norse failure to maintain colonies in Greenland, the collapse of ancient cultures from Mesopotamia to Central America, and the "Little Ice Age" that had been experienced from the 14th through 19th centuries - a "period of abruptly shifting climate regimes and more severe winters [that] had profound agricultural, economic, and political impacts in Europe and North America and changed the course of history." For the Davos audience, this talk was getting close to home. While not seeking to refute estimates of incremental climate change that were published by bodies such as the IPCC, Gagosian cautioned that the ranges and effects that such estimates provided could be much more difficult to handle if realized over much shorter periods of time with little advance warning. Impacts needed to be assessed for "many climate affected sectors…[such as]…agriculture; water resources; energy resources; forest and timber management; transportation; insurance; recreation and tourism; disaster relief; and public health (associated with climate-related, vector-borne diseases such as malaria and cholera)." He echoed the NRC's concern that developing countries were less capable of adapting to change and that adverse impacts might "spill across national boundaries, through human and biotic migration, economic shocks, and political aftershocks…." With a last-thought pitch for increased ocean monitoring networks and support for further research into thermohaline circulation as a trigger for abrupt climate change, Dr. Gagosian ended his seminal lecture with the admonition that if a climate surprise might be inevitable from what has been learned about the past, "…it is *not* inevitable for society to be surprised or ill-prepared."[86]

With so many other causes for concern throughout the world at the outset of the 21st Century, and an already arduous and intellectually challenging debate over climate change occurring internationally through the forum of the UNFCCC and its associated COPs, the subject of abrupt climate change as a matter of national concern if not national security – as clearly as it was stated by Dr. Gagosian at Davos – did not reverberate in the press. Less than two months after Davos, U.S. troops invaded Iraq to oust the regime of longtime nemesis Saddam Hussein after a lengthy and contentious buildup of forces and a painfully effete

[86] Ibid. (accessed).

start-and-stop effort to verify Iraq's compliance with United Nations resolutions related to its weapons programs that dominated international headlines because of opposition to the American alternative of invasion. With ongoing involvement in Afghanistan against holdouts of the ousted Taliban Regime and elements of Al Qaeda – including potentially its leader Osama bin Laden – that spilled continuously over the border into the Pakastani frontier, the American military had its hands full of more prosaic (if perhaps unconventional and asymmetric by American standards) problems than abstract trepidation over how climate changes might further exacerbate security concerns. Inflamed rhetoric over America's actions in initiating hostilities held more of the public's attention on television and in the newspaper headlines. Potentially remote problems don't have quite the same cachet for arousing public opinion as ones that involve the flag-draped returns of fallen soldiers and the rising number of severely wounded veterans profiled on the news, in newspaper and magazine articles, and as subjects of television documentaries and even entertainment programs that highlighted participants' war service as celebrity. Obvious threats with many visible examples can easily overshadow less concrete ones; nevertheless, even with lower visibility, the potential for abrupt climate change to manifest as a matter of concern because of its security implications slowly was gaining traction…

Security Climate…The Pentagon Considers Climate Change?

Within American Defense circles, the United States Department of Defense's Office of Net Assessment has a certain aura of either paranormal vision or paranoid delusion, depending on one's persuasion. Charged with thinking "outside the box" about security, the small think-tank within the Pentagon has been led by the same man since its inception in 1973, yet has adapted in remarkably nimble fashion to changes in the security climate for the United States in advocating strategies and technologies not at all in line with conventional defense orthodoxies. Considering the constituencies that are favored or receive less than enthusiastic support from such thinking, it is not surprising that an office whose director Andrew Marshall has been reappointed by every Secretary of Defense through changes of six Administrations and could logically be assumed to have reasonable access to the offices of power might have its equal share of proponents and detractors. Nevertheless the Office of Net Assessment provides at least an alternative view

to the “way things are done” for situations that are not at all the types that have been faced before in a world of ever changing security paradigms. Even in its name, ONA provides an alternative view, its objective being to “provide an even-handed look at both sides of complex military competitions, examining the long-term trends and present factors that govern the capabilities of the United States and its enemies. In particular Marshall had a penchant for historical case studies which proved especially useful for highlighting the political, social, cultural, and ideological dynamics that affect military developments. Studies sponsored by his office were highly influential in shaping opinions in the defense, intelligence, and foreign policy communities.”[87]

Another estimate of the Office of Net Assessment’s efforts remarks upon the challenge of its charter to tackle “futuristic threats, often the ones that the rest of the Pentagon is fearful of tackling.”[88] There is little to confirm ONA’s influence within the Pentagon, but some analysts deem it considerable, “Although little known to the general public, the office has often been much more influential than its obscure title suggests. Its an in-house think tank for DOD charged with looking at ten or twenty years into the future, sizing up threats the United States will face, and analyzing how we will match them.”[89] Comprehensive military threat estimates of this nature go beyond the scope of traditional military intelligence; it is of note that some military staffs have replaced their traditional J2, G2, and N2 nomenclatures for intelligence-related functions which now fall under the purview of Operational Net Assessment architectures. While the Pentagon was enmeshed in the military operations in Afghanistan and the buildup towards Iraq, the Office of Net Assessment remained at liberty to consider the future, and in this context a new potential concern arose on its agenda in 2003: abrupt climate change.

Responding to the National Research Council’s report *Abrupt Climate Change: Inevitable Surprises*, Office of Net Assessment director Andy Marshall commissioned an analysis by an independent think tank to contemplate the possible challenges the United States might face in the context of a sudden climatic

[87] James Carafano, "Dynamics of Military Revolution," *Richmond Independent News*, September 13, 2002.
[88] Ken Silverstein, "The Man from ONA," *The Nation*, October 25, 1999.
[89] Bert Berkowitz, "War in the Information Age," *The Hoover Digest*, no. 2 (2002).

shift.[90] Touted in some circles as a “secret” or “suppressed” memorandum that was subsequently released to the press, the report was in fact unclassified and posted online by its authors not long after completion.[91] And interestingly enough, it was first shared outside the Pentagon at Marshall’s assent with a reporter from the business magazine *Fortune* in January 2004. Conspiracy theories might abound over such a selection rather than more traditional sources of defense news and interest, but it is an interesting parallel to the talk by Dr. Gagosian of Woods Hole one year earlier to a business forum at Davos. Perhaps the futurist Marshall considered that interest by industry might spur innovative responses to the challenges posed by abrupt climate change that threatened sectors outside of the military realm and that held enormous economic ramifications. While critics sometimes complain that military leaders prepare to “fight the last war” that may or may not come to pass in an era of shifting security paradigms, for their part industry leaders are often more nimble in maintaining relevance with respect to dynamic business environments since capitalist markets quickly reward successful early innovators with market share and profits, and more conservative followers with bankruptcy. If Director Marshall was looking to the lessons of the business world, he was not saying so, preferring instead a dry statement of intent, “The Defense department continuously looks ahead to ensure that we are prepared in the future for any contingency.”[92] In any event the *Fortune* article explicitly connected the dots between the military concern expressed by Marshall’s sponsorship of the assessment and the validity of scientific *gravitas* by virtue of Dr. Gagosian’s Davos speech.

The scenario laid out in the ONA report “An Abrupt Climate Change Scenario and Its Implication for United States National Security” actually reads much like Dr. Gagosian’s talk at Davos, but goes into even greater speculative detail about what the potential climatic changes might mean from a political, social and security standpoint. Reflecting the research behind abrupt climate change, and both the NRC’s and Dr. Gagosian’s mutual focus on the particulars as well, the ONA analysis considers a scenario in which climate

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90 Andrew C. Revkin, "The Sky is Falling! Say Hollywood and, Yes, the Pentagon," *The New York Times*, February 29, 2004.

91 "Leaked Pentagon Report Warns of Coming Climate Wars," 2004 (accessed February 23, 2004); available from http://www.ens-newswire.com/ens/feb2004/2004-02-23-09.asp; Mark Townshend and Paul Harris, "Now the Pentagon Tells Bush: Climate Change Will Destroy Us," *The Guardian*, February 22, 2004.

92 Seth Borenstein, "If a Climate Change Shook the World," *Philadelphia Inquirer*, February 26, 2004.

is altered as a result of "a relatively abrupt slowing of the ocean's thermohaline conveyor, which could lead to harsher winter weather conditions, sharply reduced soil moisture, and more intense winds in certain regions that currently provide a significant fraction of the world's food production. With inadequate preparation, the result could be a significant drop in the human carrying capacity of the Earth's environment."[93] This was hardly the hyperbolic prose that some critics alleged.[94] The premise behind the report might have been sketched by Roger Revelle years earlier if he had connected his own concerns for warming climate with Stommel's multiple patterns of ocean circulation as did Wally Broecker; even more, with the possible exception of *abrupt* and the oceanic trigger, the climate change scenario on which the ONA security analysis was based might easily have been lifted from an executive summary written by the IPCC.

The authors of the Office of Net Assessment's report on abrupt climate change, Peter Schwartz and Doug Randall, acknowledged from the outset that they were treading on delicate issues. They described their goal as "Imagining the Unthinkable" in order to better estimate the range of effects on United States national security that scenarios of abrupt climate change might pose. The authors worked with climate scientists to determine what they estimated to be reasonable boundaries on the climate change possibilities and the range of effects on environmental parameters. Schwartz and Randall looked to the historical record to find something of a template upon which to base their scenario. They considered climate swings that ranged between the extreme of the Younger Dryas – an abrupt period of cooling approximately 13,000 years ago that experienced a temperature drop on the range of 15°C over a period of five decades in northern latitudes that lasted some 1300 years – to the more recent period known as the Little Ice Age (the example Dr. Gagosian used at Davos) that took place between the 14th and 19th centuries and which was much less dramatic geophysically but that still "brought severe winters, sudden climatic shifts, and profound agricultural, economic, and political impacts to Europe."[95] In the end, Schwartz and Randall selected an intermediate period that is recorded in the records 8,200 years into the past, an event that was

[93] Peter Schwartz and Doug Randall, *An Abrupt Climate Change Scenario and Its Implications for United States National Security* (San Francisco: Global Business Network, 2003).
[94] Robert C. Balling, "Pentagonal Poppycock," 2004 (accessed June 3, 2006); available from http://www.tcsdaily.com/article.aspx?id=030104E.
[95] Schwartz and Randall, *An Abrupt Climate Change Scenario and Its Implications for United States National Security*.

theorized to have taken place when the Laurentide ice sheets might have melted enough to allow Lake Aggasiz to drain into the North Atlantic and interrupt thermohaline circulation.[96] This 8.2K event followed up a period of prolonged incremental atmospheric warning with a rather precipitous drop of almost 3°C in Greenland (as recorded in ice cores) over a matter of decades with similar plunges projected throughout Europe that appear to have lasted for a century. As a result, "During the 8,200 year event severe winters in Europe and some other areas caused glaciers to advance, rivers to freeze, and agricultural lands to be less productive."[97]

Considering current concern over a lengthy period of atmospheric warming, and indications such as those reported at Davos by Dr. Gagosian about freshening of waters in the Labrador Sea with attendant uncertainty about what this means for ocean circulation, this scenario is somewhat uncomfortably close to home. Schwartz and Randall selected it not be apocalyptic, but rather because they needed a shift at least extreme enough to "explore implications for food supply, health and disease, commerce and trade, and their consequences for national security" in order to "forecast the *strategic conversation* [emphasis added] rather than to accurately forecast what is likely to happen with a high degree of certainty."[98] Avoiding easy criticism for basing their scenario on unreasonable estimates of the future, they chose instead to reach into history for an example of what *had* occurred during the time humans populated the Earth; the social and political ramifications of this particular event in history, after all, led some scientists and historians to consider it the watershed event leading to civilization as understood by modern society.[99] Nevertheless the authors prefaced their report with the caveat that their product scenario was considered by some of the climate scientists that they consulted to be more extensive geographically and perhaps in magnitude than might be expected to take place. Even so, it was a more conservative road to take than speculating about events not known from the record, "While future weather patterns and the specific details of abrupt climate

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[96] Barber, Dyke, Hillaire-Marcel, Jennings, Andrews, Kerwin, Bilodeau, McNeely, Southon, Morehead, and Gagnon, "Forcing of the Cold Event of 8200 Years Ago by Catastrophic Drainage of Laurentide Lakes."
[97] Schwartz and Randall, *An Abrupt Climate Change Scenario and Its Implications for United States National Security*.
[98] Ibid., 5, 7.
[99] deMenocal, "Cultural Responses to Climate Change During the Late Holocene."; Fagan, *Floods, Famines, and Emperors;* Weiss, Courty, Wetterstrom, Guichard, Senior, Meadow, and Curnow, "The Genesis and Collapse of Third Millenium North Mesopotamian Civilization."

change cannot be predicted accurately or with great assurance, the actual history of climate change provides some useful guides. Our goal is merely to portray a plausible scenario, similar to one which has already occurred in human experience, for which there is reasonable evidence so that we may further explore potential implications for United States national security."[100]

The climate change situation envisioned by Schwartz and Randall begins with a period of incremental atmospheric warming of between .3°C to 1.2°C per decade varying by region and season and "continuing the warming trend of the late 20th century" for this early 21st century scenario. Many land areas experience 30% more days with peak temperatures that exceed 32°C and fewer days below freezing; erratic weather patterns lead to flooding in mountainous regions and droughts in important agricultural areas. "In general, the climate shift is an economic nuisance…not yet severe enough or widespread enough to threaten the interconnected global society or United States national security." Eventually however, feedbacks in the climate system kick in and annual temperature increases inch upwards which in turn accelerates the hydrologic cycle of evaporation, precipitation and runoff. More water vapor in the atmosphere exacerbates the greenhouse effect and the climate continues to warm at an accelerating rate. Forests and grasslands die off, reducing opportunities for carbon uptake. Snow cover melts as does permafrost, reducing reflectivity and increasing thermal absorption while also freeing more carbon to the atmosphere. The process continues… More severe storms bring higher surges and floods into low-lying areas, breaching dams and levees and disrupting fresh water transportation systems which in turn disrupt agriculture and industry dependent on these flows. Glaciers melt; sea level rises; wave action increases and erodes coastlines and places millions at risk of flooding. Fisheries become disrupted by altered patterns of circulation and ocean temperatures. "Each of these local disasters caused by severe weather impacts surrounding areas whose natural, human, and economic resources are tapped to aid in recovery."[101]

The impacts Schwartz and Randall speculate do not spread the wealth evenly, and are "greatest in less-resilient developing nations, which do not have the capacity built into their social, economic, and

[100] Schwartz and Randall, *An Abrupt Climate Change Scenario and Its Implications for United States National Security*, 5.
[101] Ibid., 9.

agricultural systems to absorb change." Meanwhile, increased ice melt and runoff from elevated high-latitude precipitation continues to freshen ocean surface waters, and the "lower densities of these freshened waters in turn pave the way for a sharp slowing of the thermohaline circulation system." Having forecast the trends from the last four decades of the 20th century to the end of the first decade of the 21st, Schwartz and Randall indicate that more than fifty years of freshening these northern waters leads to a sudden collapse of the THC over the course of a few years, with resulting changes in circulation that starve the northern latitudes of warmth brought by the Gulf Stream, causing "an immediate shift in the weather in Northern Europe and eastern North America…[and] cooler temperatures…and a dramatic drop in rainfall in many key agricultural and populated areas." The slowdown in THC had been "anticipated by some ocean researchers, but the United States [was] not sufficiently prepared for its effects, timing, or intensity…and unable to produce sufficiently consistent and accurate information for policymakers." Uncertainty over future changes leads researchers to differ over whether additional cooling and dryness is to be expected even to the point of a new ice age or a global drought, "leaving policy makers and the public highly uncertain about the future climate and what to do, if anything. Is this merely a "blip" of little importance or a fundamental change in the Earth's climate, requiring an urgent massive human response?"[102]

By the end of the second decade of this rapid climate change scenario, temperatures in northern latitudes drop another 3°C or more. Average rainfall diminishes by nearly 30% and winds become up to 15% stronger, leading to dry conditions conducive to soil erosion. With time, these harsh conditions migrate southward, affecting more population centers and agricultural regions. Europe becomes "colder, drier, and windier, making it more like Siberia," and soil loss from reduced precipitation contributes to food supply shortages; in addition, "Europe struggles to stem emigration out of Scandinavian and northern European nations in search of warmth as well as immigration from hard-hit countries in Africa and elsewhere." In the United States, "Colder, windier, and drier weather makes growing seasons shorter and less productive…." Rising seas place its coastlines at risk, and "The United States turns inward, committing its resources to feeding its own population, shoring-up its borders, and managing the increased global

[102] Ibid., 10.

tension." Schwartz and Randall step through regions of Southeast Asia and Africa painting similar scenarios of climate change, environmental degradation, and severe societal impacts which cause states to look elsewhere to obtain necessary resources and relieve growing strains on internal carrying capacity that have been worsened by environmental migrations of refugees. Insufficient surpluses in food growing regions is available to meet swelling demand, and economic interdependence makes "the United States increasingly vulnerable to the economic disruption created by local weather shifts in key agricultural and high population areas around the world. Catastrophic shortages of water and energy supply – both of which are stressed around the globe today – cannot be quickly overcome."[103]

Schwartz and Randall's scenario depicts an unending litany of woes that led some scientists they consulted to caution about the extent to which the authors went to depict potential impacts of climate change. But the authors address this, "Modern civilization has never experienced weather conditions as persistently disruptive as the ones outlined in this scenario. As a result, the implications for national security outlined in this report are only hypothetical. The actual impacts would vary greatly depending on the nuances of the weather conditions, the adaptability of humanity, and decisions by policymakers." The authors consider the magnitude of change to be such that expectations for human behavior may need to be altered, "Military confrontation may be triggered by a desperate need for natural resources such as energy, food and water rather than by conflicts over ideology, religion, or national honor. The shifting motivation for confrontation would alter which countries are most vulnerable and existing warning signs for security threats."[104] This is the language of environmental security as it grew not long after the Cold War; however for most of the intervening period the field has faltered because few of these almost biblical environmental threats could be demonstrated or envisioned even under scenarios illustrated by the IPCC depicting the nature of incremental climate change. But theories of abrupt climate change could point to more dramatic swings in environmental parameters and in the timing of events similar to those found within the historical

[103] Ibid., 13-14.
[104] Ibid., 14.

record, and open the door to reconsideration of aspects within environmental security that heretofore have been somewhat marginalized.[105]

The next analytical step taken by Schwartz and Randall in their ONA report related to potential *responses* to environmental challenges. "In the event of abrupt climate change, it's likely that food, water, and energy resource constraints will first be managed through economic, political, and diplomatic means such as treaties and trade embargoes. Over time though, conflicts over land and water use are likely to become more severe – and more violent. As states become increasingly desperate, the pressure for action will grow."[106] The authors question whether technology will be able to keep pace with the rate of change and challenges posed by abrupt climate change to sustain the requisite needs for food, water, and energy of the global population. States with high carrying capacities – which the authors define globally as "the ability for the Earth and its natural ecosystems including social, economic, and cultural systems to support the finite number of people on the planet" and consider regionally as a function of these systems at finer resolution – are estimated to be capable of adapting most effectively to changing climate. But this too, may be a problem as it "may give rise to a more severe have, have-not mentality, causing resentment towards those nations with a higher carrying capacity. It may lead to finger-pointing and blame, as the wealthier nations tend to use more energy and emit more greenhouse gases such as CO_2 into the atmosphere." While much remains to be understood about anthropogenic responsibility for climate change, what matters according to Schwartz and Randall is "the perception that impacted nations have – and the actions they take."[107]

Establishing an unequivocal link between environmental degradation and its potential for decreased carrying capacity to an extent that makes it coincident with the occurrence of warfare is more problematic for the authors, and perhaps the most speculative section of their thought-piece – even more so than any

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[105] Jon Barnett, "Environmental Security and U.S. Foreign Policy: A Critical Examination," in *The Environment, Foreign Relations, and U.S. Foreign Policy*, ed. Paul G. Harris (Washington: Georgetown University Press, 2001); Max G. Manwaring, "The Environment as a Global Stability-Security Issue," in *Environmental Security and Global Stability*, ed. Max G. Manwaring (Lanham: Lexington Books, 2002).
[106] Schwartz and Randall, *An Abrupt Climate Change Scenario and Its Implications for United States National Security*, 15.
[107] Ibid., 16.

possible forecasts for abrupt climate change. This is the link that environmental security has wrestled with…and largely failed to establish conclusively to date. Schwartz and Randall call on the research of Steven LeBlanc, an archaeologist who posited that this link in fact exists, and that "historically humans conducted organized warfare for a variety of reasons, including warfare over resources and the environment. Humans fight when they outstrip the carrying capacity of their natural environment. Every time there is a choice between starving and raiding, humans raid." Things that contribute to carrying capacity – such as the invention of agriculture, trade and technology – help ameliorate conflict, but when limits to carrying capacity are again met, conflict renews. And in these instances, "The most combative societies are the ones that survive."[108]

Because the images these scenes invoke are reminiscent of post-apocalyptic science fiction fare, pundits that criticize the ONA report deride such lines of thought as interpreting changes in the climate to be "plunging us into a *Mad Max*-style world rife with resource wars."[109] Herein is the essential disconnect which deflates many environmental security theories: it is difficult to find instances where conflict broke out over environmental problems without other critical exacerbating factors. Then again as Schwartz and Randall point out, never before has *man* – at least in organized society – faced such challenges as abrupt climate change with the impacts it may bring. And no one has claimed that other critical exacerbating factors would not exist; in fact in the post-Cold war world it has been ever more apparent that potentially divisive factors such as race, religion, ethnicity, and culture are widely prevalent, not to mention numerous political rifts of varying stripe. Superimposed upon these tensions, climate changes as severe as those posited in the ONA scenario would sorely test the ability for peoples and states to arrive cooperatively and harmoniously at solutions to problems that threaten the most basic levels of their security.

If they were able to look to the historical climate record to substantiate their ideas for potential future climate shifts, Schwartz and Randall must extrapolate considerably to arrive at potential actions that the United States and other countries might take in the face of abrupt climate change. They posit the

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[108] Ibid.
[109] Alexander Zaitchik, "The Day After Tomorrow: Yoda Levitates the Pentagon; National Security Goes Green," *New York Press* 2004.

adaptation of defensive and offensive strategies that seek either to prevent others from impinging upon reserves or that intend to take just that course of action, by aggression if necessary. The U.S. is foreseen to have enough capacity to sustain its own population, but is expected to circle the wagons to prevent an influx of refugees from Mexico, the Caribbean, and South America. While Europe struggles to feed its own and the many who have fled from more harsh climes, temptingly just across the border with Russia there are greater supplies of grain, minerals and energy. Japan similarly sees in Russian energy reserves the capacity to power its desalination plants and energy-intensive agriculture. Border problems due to refugees arise at the intersection of Pakistan, India and China. Historical fishing rights for countries such as Spain and Portugal become an issue now that fish have migrated to other ocean provinces. And because of their importance for drinking water, irrigation and transportation river boundaries are potentially scenes of confrontation rather than cooperation. With a world of warring states, weapons proliferation becomes a major problem – especially nuclear proliferation since more states must rely on nuclear power to satisfy energy needs and therefore have within their reach the means to reprocess and enrich nuclear materials.

"Managing the military and political tension, occasional skirmishes, and threat of war will be a challenge," allege Schwartz and Randall, adding that countries with greater social cohesion will fare better than those with internal diversity that already complicate their domestic situations. Where adaptability and access to natural resources are considered the keys to meeting the challenges of abrupt climate change, "Perhaps the most frustrating challenge…is that we'll never know how far we are into the climate change scenario and how many more years – 10, 100, 1000 – remain before some kind of return to warmer conditions as the thermohaline circulation starts up again." In the meantime Schwartz and Randall conclude that certain strategies could be employed to meet the uncertain climate future. They recommend improvements in climate models to help predict future states; call for research on potential ecological, economic, social and political impacts of abrupt climate change in order to mitigate sources of conflict; suggest the creation of vulnerability indices based upon such factors as agricultural, water and mineral resources, and upon technical capability, social cohesion and adaptability in order to pre-plan responses; identify no-regrets strategies as means to ensure reliable access to food and water; advise preparation of adaptive responses led by teams capable of addressing issues related to refugee migrations, disease and

epidemics, and food and water supply shortages; emphasize the importance of knowledge about local conditions in determining the depth of impact to be expected, especially in areas important for agriculture; and finally recommend that the full spectrum of science and technology be employed in seeking ways to mitigate changes that threatened human beings and society in general.[110]

The reception in the press to the Office of Net Assessment's thought-piece was interesting, and indicative of earlier frustrated efforts to register environmental security higher on the scale of security considerations. Climate change was no stranger to national or international headlines, but taken to the extremes where it might induce or contribute to conflict it met with dubious critiques. "Now the Pentagon Tells Bush: Climate Change Will Destroy Us."[111] "Leaked Pentagon Report Warns of Coming Climate Wars."[112] "If a Climate Change Shook the World: Famine and Nuclear Battles are Possible Should a Drastic Shift Occur, Futurists Tell the Pentagon."[113] "The Sky is Falling! Say Hollywood and, Yes, the Pentagon."[114] "Pentagonal Poppycock."[115] "The Day After Tomorrow: Yoda Levitates the Pentagon; National Security Goes Green."[116] Even the article that ONA Director Marshall had authorized did little to elevate the tone, "Climate Collapse: The Pentagon's Weather Nightmare."[117] Some of the articles provided at least a sense of the rationale behind the effort – both the necessity for the Pentagon to consider potential threats to national security and Schwartz and Randall's efforts to draft a plausible scenario – but the headlines provide the distillation. "Jeremiad" is not normally a term applied to a rationally thought out scenario requiring the dedicated efforts of the U.S. Defense Department to consider its ramifications.[118]

The ONA analysis also had the misfortune of being revealed to the public not long before the Hollywood movie "The Day After Tomorrow" was released in movie theaters across America. In this cinematic offering, an abrupt climate change scenario begins with changes in ocean circulation, but

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[110] Schwartz and Randall, *An Abrupt Climate Change Scenario and Its Implications for United States National Security*.
[111] Townshend and Harris, "Now the Pentagon Tells Bush: Climate Change Will Destroy Us."
[112] "Leaked Pentagon Report Warns of Coming Climate Wars," (accessed).
[113] Borenstein, "If a Climate Change Shook the World."
[114] Revkin, "The Sky is Falling! Say Hollywood and, Yes, the Pentagon."
[115] Balling, "Pentagonal Poppycock," (accessed).
[116] Zaitchik, "The Day After Tomorrow: Yoda Levitates the Pentagon; National Security Goes Green."
[117] David Stipp, "Climate Collapse: The Pentagon's Weather Nightmare," *Fortune*, January 26, 2004.
[118] Ibid.

accelerates so quickly with such catastrophic impacts that it renders the science of climate change as utter science fiction. With movie trailers on television and in theaters months beforehand, the authors who critiqued the ONA report after the *Fortune* article was published conflated much of the drama of Scwhartz and Randall's scenario with the melodrama of the soon-to-be-released movie. Although the movie's director claimed that he wanted to instigate discussion over the dangerous potential for climate change, he may in fact have caricatured it as a farcical "What Next from the Deep Thinkers at the Pentagon?" Pre-release publicity hyped the political divisiveness of the issue, calling the blockbuster "the movie the White House doesn't want you to see" because of the Administration's opposition to climate change initiatives such as the Kyoto protocol.[119]

Scientists on the other hand, were less than enthusiastic about climate issues reaching the public in this fashion, worrying that the extremes portrayed on film might damage the very real dialogue in academia and as an incipient matter of security.[120] Playing to the sound bite mentality of the movie-going public might have helped sell tickets, but it also conflated the issue with the other goal of the picture: entertainment. And entertainment value lasts about as long as the time until the next blockbuster is released – maybe a week, especially during the summer season. If Davos had raised the possibility for abrupt climate change to reach the attention of policy makers and business leaders, and the ONA assessment had potentially elevated it even higher as a security concern, the coincidental release of "The Day After Tomorrow" may have deflated it immeasurably. Climate change remained in the public discourse, but a critical opportunity for *abrupt* aspects of the issue to ratchet the subject higher on the list of national priorities was squandered with the popcorn that littered movie theaters around the country.

Failure to gain traction as a *popular* national issue does not necessarily mean that the issue of abrupt climate change would fade from attention altogether. Its very real potential to affect security meant that at some other level those assigned to sift the wheat from the chaff of security concerns might yet winnow the

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[119] Natasha Robertson, "Storm Warning: Not Only Action Fans are Awaiting 'The Day After Tomorrow'," *Boston Sunday Globe*, May 23, 2004.
[120] Ty Burr, "Will Watching Global Warming Wreak Havoc on Film Make It Seem More Real, or Less?," *Boston Sunday Globe*, 2004; Julie Kirkwood, "Could THIS Happen? Blockbuster Takes Liberties With Global Warming," *The Daily News*, May 24, 2004; James M. Taylor, "Hollywood's Fake Take on Global Warming," *The Boston Globe*, June 01, 2004.

issue from amidst the clutter of the public banter caused by the *Fortune* article and "The Day After Tomorrow." The same month that Schwartz and Randall published their analysis for the Office of Net Assessment - but before the public became aware of the issue via the *Fortune* article - in October 2003 Dr. Bob Gagosian and Rear Admiral (Ret.) Dick Pittenger published their National Defense University essay on the effects that climate change might have for military operations. The article is essentially Gagosian's Davos talk expanded into areas more *apropos* to naval strategists. In their overview for "Global Warming Could Have a Chilling Effect on the Military," Pittenger and Gagosian highlight evidence for abrupt climate change scenarios instead of gradual ones, the potential for the climate system to cross critical thresholds that shift between modes, and the possibility that change might be more apparent regionally instead of globally. They emphasize the nonlinearity of the climate system's potential responses to triggers, and they warn that this issue is hardly "on the radar screen of military planners, who treat climate change as a long-term, low-level threat, with mostly sociological, not national security, implications."[121]

Pittenger and Gagosian opine that "intense and abrupt climate changes could escalate environmental issues into unanticipated security threats, and could compromise an unprepared military." They explain the implications for oceanic change with respect to climate change, and they offer that "Recent evidence suggests that the oceans already may be experiencing large-scale changes that could affect Earth's climate. *Military planners should begin to consider potential abrupt climate change scenarios and their impact on national defense* [emphasis added]." The bulk of their essay reviews much of the same material that Gagosian presented to his Davos listeners, but writing for a military audience they emphasize that the issue requires urgent review from a security perspective, especially with regards to the potential rate that abrupt climate change scenarios imply as compared to the more prevailing views of incremental change. "The prevailing US military attitude is that a wealthy superpower has ample time and resources to adapt to gradual and anticipated climate change. In the meantime, the primary US military strategies on climate change involve publicized efforts to reduce greenhouse gas emissions and fuel consumption. They foresee few, if any, climate-induced security threats." [122]

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[121] Pittenger and Gagosian, "Global Warming Could Have a Chilling Effect on the Military."
[122] Ibid.

Citing the paper "Redefining Security" by Richard Ullman that was instrumental in establishing environmental considerations as elements of security not long after the Cold War, Pittenger and Gagosian identify "natural security" threats as "anything that can quickly degrade the quality of life of the inhabitants of a state or narrow the choices available to people and organizations within the state." This, they assert, is exactly what abrupt climate change portends, "…rapid climate changes that can have large detrimental impacts on agriculture, water resources, energy resources, fisheries, transportation, economic activities, disaster relief, and public health (associated with climate related, vector-borne diseases, such as malaria and cholera, for example)." They went on, "It does not take a lot of imagination…to envision how deleterious changes in the monsoons in South Asia (which encompasses half the world's population and several nuclear-armed nations) could escalate quickly into security threats for the United States; or how an abrupt climate cooling in the North Atlantic region could lead to consecutive severe winters that tax the energy resources and economies of the US and Europe – quickly degrading inhabitants' quality of life and narrowing the choices available to them."[123] This vignette of Pittenger and Gagosian's speculative essay is similar to the one posited by Schwartz and Randall, even without the more fully drawn scenario that the ONA paper presented. While persuasive, however, both were also pegged to the language of environmental security which had been relegated to somewhat lesser sidebars of contemporary security thought – irrespective of their potential as more essential elements of security paradigms in the future.

Throughout the ONA report of Schwartz and Randall, and thus far from what has been recounted of the NDU report by Pittenger and Gagosian, the climate change scenarios under discussion are *strategic*. The main points are registered at broad national and international levels as problems to be faced through decisions of national policy and as matters of international negotiation and comity…or conflict. As arguments to be considered within the hierarchy of 21st Century security matters, they must contend with their own uncertainties and with more concrete strategic issues of national security including transnational terror that dominate daily headlines and security thinking. When military – and in the case of this dissertation *naval* – attention was focused earlier on matters of environmental importance, they were largely at *operational* and *tactical* levels of warfare. Throughout the Cold War, U.S. and Soviet plans

[123] Ibid.

centered on the use – or more appropriately the *threat* of using – nuclear weapons in steering the course of strategic policy with respect to their opponent. The foreign policies of each superpower were shaped by this strategy, and consequently so were the policies of most of the adjunct participants and spectators to this rivalry.

At the operational level, the world was divided into theaters in which control was exercised by fleets of ships, aircraft and ballistic missile submarines which could exercise this atomic strategy by their ability to deliver warheads to critical nodes of rivals. With time and technology, the increasing range arc of intercontinental ballistic missiles made operational maneuvering such as that which took place in the Arctic or that is reflected in the Cuban Missile Crisis somewhat obsolete. Invulnerability became the imperative, and operational maneuver became a matter of ensuring second-strike capacity that underpinned nuclear strategy by maintaining a viable deterrent at all times to the opponent's option of exercising a first-strike. This operational maneuvering meant maintaining both hardened and agile land-based missiles, a nimble fleet of long-range bomber aircraft, and an undetectable subsurface threat protected by the opacity of the world's oceans from enemy detection.

Tactical considerations remained at the individual platform level and perhaps as high as the squadron, division, or naval battlegroup level; these considerations involved the factors that determined victory when these units faced each other in open combat. Naval operations in general and oceanographic relevance to naval operations in particular resonated primarily at operational and tactical levels under the overarching nuclear strategy. Control or dominance of areas of the open ocean, sea lanes of communication, and chokepoints in implementing the undersea leg of the nuclear triad were achieved at the operational level of warfare. This includes the U.S. stratagem of monitoring Soviet submarine movements through these areas and throughout their deployments by means of the IUSS system thus supporting nuclear strategy at the operational level. Once IUSS cued submarine movements to frontline forces, tactical considerations such as the impact of thermohaline fronts and eddies on sensor and weapon system performance became the oceanographic component of interest. The levels of warfare are not entirely separable, and aspects as well as particular weapons and platforms might be binned appropriately in one or the other (or both) at various

times in the analysis of this decades-long conflict, but what is significant is that the environmental constraints that necessitated the study of the oceans in support of security priorities were primarily at the operational and tactical levels. With climate change scenarios providing most of their predictive power at the strategic level, environmental security issues face an additional paradigm to overcome to gain acceptance among security specialists (who in turn advise policy makers)…unless climate change can be shown to affect these other two levels of military focus and planning. In this respect, Schwartz and Randall did not delve deep enough; Pittenger and Gagosian however, were not finished….

After a thirty-seven year naval career that spanned much of the Cold War, Rear Admiral Dick Pittenger was no stranger to antisubmarine warfare. In fact he had been at one point the Director of the Antisubmarine Warfare Division of the staff on the Chief of Naval Operations, and was the author of many naval articles on ASW training and fleet tactics.[124] Potential changes to the circulation of the North Atlantic Ocean held obvious implications to a naval officer schooled in chasing Soviet submarines. Significant alteration of the temperature and salinity structure of the water column posed immediate military challenges, "…acoustic paths…formed the basis for all of the US and allied Anti-Submarine Warfare (ASW) Sensor Systems and aided significantly in winning the ASW battle of the Cold War. A rapidly changing ocean environment could invalidate existing acoustic predictions, which use historic climatology to calculate acoustic paths, propagation loss, bottom loss, and ambient noise."[125] Indeed, something there is that doesn't love an ASWEPS forecast…

Pittenger and Gagosian described how windier conditions might alter ambient noise considerations, how sound channels might vary dramatically or disappear altogether, and how different acoustic paths would require "adjustments on all tactical platform (air, sub, surface) sensors…[that] would require reengineering, redesign, or even relocation of systems." The Navy depended upon "ocean environmental nowcasts and forecasts of sea and wave heights and directions, marine and aviation weather, ocean current fronts and eddies, and long- and short-range acoustic propagation.... All of these products use existing models and

[124] "Science, Salt Water, Submarines and Symbiosis: Doing R&D with the Navy," *Knowledge for Development Research Seminar*, 2003 (accessed June 25, 2006); available from http://www.ksg.harvard.edu/sed/docs/k4dev/pittenger_bio2003.pdf.
[125] Pittenger and Gagosian, "Global Warming Could Have a Chilling Effect on the Military."

historic climatology as their backgrounds. All would be impacted (some severely), should the climatology be invalidated by abrupt climate change." Naval forces potentially faced additional challenges as well; cooler conditions along the U.S. East Coast might freeze port approaches and harbors and impact naval operations, especially at Norfolk, Virginia – the largest naval concentration in the world; similar problems at the U.S. submarine base in Groton, Connecticut could be expected as well as in many commercial ports including those that contract-crewed military logistic ships utilized. The authors describe a particularly bad winter in the 1970s in which harbors froze solid and ice damaged navigational aids throughout Chesapeake Bay.

Naval operations overseas might also be affected through teleconnections of climate change from the North Atlantic to areas as far away as the Arabian Sea; while ice would not likely ever be a factor there, other atmospheric and oceanographic effects on naval operations could be expected. Changes in prevailing winds, air temperature, humidity and atmospheric aerosols would affect aviation operations and weapons selection and performance considerations; in the oceans cool current jets formed by wind-induced upwelling might pose acoustic challenges to ASW defense of aircraft carrier battlegroups. Around chokepoints such as the Strait of Hormuz this might throw operational maneuver throughout the region into question. Naval tactics, techniques and procedures (TTPs) to operate in altered environmental battlespaces would have to change…[126] With the many considerations that Pittenger and Gagosian identify at tactical and operational levels of naval warfare, the battlefield could be a very different place under scenarios of abrupt climate change.

In their NDU essay Pittenger and Gagosian also point out that climate change scenarios – abrupt or otherwise – pose a host of challenges with respect to naval operations in the Arctic, a region which does not figure prominently in contemporary naval activity but that throughout the Cold War represented a key area of operations. For all Soviet naval forces, voyages from northern ports required some measure of travel through Arctic waters; over-the-pole missile shots reduced range requirements of ballistic missiles; and submarines of both stripes were no strangers to the areas where they hunted each other beneath the ice.

[126] Ibid.

Acoustic operations in a warmer and potentially ice-free Arctic would prove altogether different than Cold War operations near and under the polar ice; generally speaking submarines would become more vulnerable under such conditions in a relatively shallow ocean basin. With the dissolution of the Soviet Union, much of the threat that occupied U.S. forces for decades in the Arctic disappeared; nevertheless, climatic changes in the Arctic might pose new considerations, even without the Soviet submarine one.[127]

A potentially ice-free (at least partially) Arctic raises the possibility of a navigable route from Atlantic to Pacific that could save considerable distances over routes around South America or Africa, and even circumnavigations that voyaged through the Panama Canal which has an additional limitation based upon overall length and especially the beam-width of ever growing supercarriers. Law of the Sea considerations and sensitivities might arise among the nations that border this province, especially with respect to passage through previously protected and pristine seas that hold other economic or cultural importance to these countries. Accidental pollution of fragile Arctic ecosystems that are not as dynamic as those of more temperate zones would make recovery lengthy and difficult. The area would become at least seasonally accessible to the naval forces of nations that previously lacked under-ice capability in their submarines, icebreaker capability, or reinforced hulls in their naval surface vessels. Assuming that these waters would not remain ice-free throughout the year, a requirement for *more* ice-capable ships would arise at a time when few are available to the U.S. Navy, and virtually all under-ice capable submarines have been depleted from the inventory while post-Cold War designs failed to include this capacity altogether. Research and development for Arctic issues plummeted from over $30 million dollars per year during the Cold War to less than a tenth of that figure afterwards. A planning analysis conducted around the time of Pittenger and Gagosian's essay indicated that naval forces operating in a (near) ice-free Arctic faced some critical challenges including: inadequate charts and navigational training; sensor, weapons, and communications performance including extreme cold weather modifications to systems such ice-clearing mechanisms for phased array radars; environmental modeling and prediction; hull design and performance and stability modeling; Arctic-capable damage control systems; icebreakers; and Arctic tactics including war game

[127] Ibid.

scenarios that would train naval crews to perform in new conditions. Climate change portended a brave new world for naval operations at high latitudes – one the U.S. Navy was (is) unprepared to take on.[128]

Designing an ice-capable surface and subsurface fleet is not a likely course of action for the United States Navy at any time in the near future. Faced with immediate deployments to the ongoing crises in the Middle East and Southwest Asia as well as to potential hotspots in Southeast Asia, ice is not high on the planning agenda. Nevertheless, the considerations that Pittenger and Gagosian outlined are worthy of contemplation, and in some important aspects considerable investment in thought. Even if near-term naval battlefields are not Arctic ones – the considerations there must be first whether Arctic nations such as Canada, the United States, Russia, and the Scandinavian governments would be more likely to negotiate necessary accommodations for handling the ramifications for a nearly ice-free ocean or fight over them – the flexibility to adapt to changing climatological conditions might be required for naval operations even far from the poles. Naval forces may not be able to rely on existing climatologies if global climate change significantly alters conditions in the oceans where they must operate.

This touches on two areas of environmentally constrained operations: the first involves the safe and efficient movement to objective areas as well as sustained operations in these areas under ambient environmental conditions including wind regimes, wave activity, tidal variance and ocean currents; and the second acknowledges the subsurface considerations of antisubmarine warfare in various hotspots around the world that are largely dependent on environmental predictions to optimize sensor and weapons performance. Planning considerations for the first of these two factors would be dependent upon historical data that would prove questionable under climate change scenarios; substantial investment in real-time observations would be required to support planning and sustainment of such operations. With respect to the latter consideration, on-scene sampling of the ocean environment is always preferable to climatology in order to initialize predictive models or environmentally-based tactical decision aids, so perhaps little *ostensibly* changes even in the face of climate shifts; what matters here, however, is how climatologies are still integral even with the use of *in situ* observations in model initialization. Sensors are limited in their

[128] Ibid.

ability to relay information about the full extent of the water column; at some point the wires of expendable bathythermographs break and the range of conductivity-temperature-depth (CTD) probes is reached. At those data discontinuities, since deep water parameters are *assumed* to be less variable, climatological information is seamed to the *in-situ* data to initialize predictive models that determine acoustic propagation profiles.

Without *in situ* data, only climatology is available throughout the entire range of the water column – an obvious concern if climate change is afoot; even with the near-real time data, climatology impacts numerically derived predictions because of the need to provide a complete water column profile to drive numerical models…and *changes* to climatological means can be expected to affect results. This says nothing about required sampling densities for near-real time data to be of legitimate tactical use in dynamic conditions near ocean fronts or eddies – conditions that would clearly be handled poorly by climatology because of their variable nature. In areas of the littorals – where the U.S. Navy expects to encounter most 21st Century threats - the ability to collect *in situ* data may be limited, either because of adversary presence and opposition, or because of the political sensitivities of operating closer to coastlines even in peacetime that include the potential complications brought to light earlier in this chapter having to do with military survey operations within EEZs. Advanced unmanned underwater vehicles and ocean gliders have enormous potential for clandestine investigation of the water column but have limited sampling capabilities and operating constraints – not to mention political liabilities - that also proscribe their potential. Even satellite sensors – politically above the (international) law since the days of Sputnik – have limited capabilities to solve these problems because of the parametric sampling requirements, but also because of their availability, especially now that the Cold War has ended and the requirements that justified their expense have waned. In at least one instance, a satellite sensor that held particular relevance to current considerations likely will soon no longer be available for ocean investigations – with implications that are yet to be fully realized.

If Neptune Launched a Satellite

There is little doubt that the technology that enabled the placement of satellite environmental sensors in Earth orbit was developed to support security interests on both sides of the Cold War. A group of scientists that were paneled to review naval environmental datasets for their applicability to civilian research put it succinctly, "…the entire civilian, space-base remote sensing program owes its origins to earlier successes and technology of the classified satellite reconnaissance programs."[129] These reconnaissance programs in turn owed a great deal to more straightforward military considerations: putting weapons on target. Missile technology developed during World War II was exploited by both sides in designing vehicles that could deliver nuclear warheads thousands of miles to enemy military installations…or cities. However, advancing aerospace technology also made possible more than just the delivery of weapons payloads through exo-atmospheric trajectories; it made available platforms that could deliver sensors into orbit that could reconnoiter an adversary's infrastructure and military assets. This capability was only a small step from corollary missions that eventually provided the first truly synoptic view of the Earth's atmosphere and oceans, observing at a glance almost hemispheric expanses that revealed new details to scientists eager to move beyond the confines of planetary sampling and the broader yet still limited views provided by high-altitude reconnaissance aircraft. A dynamic world painted over with sinuous patterns of clouds and ocean features was revealed. Early television satellites provided grainy imagery that even in its rudimentary form greatly enhanced the ability of atmospheric scientists and oceanographers to understand features they were attempting to characterize and predict.

As technology advanced a variety of sensors were placed on orbit: visual imagers of steadily increasing pixel resolution; infrared, ultraviolet and multi-spectral sensors that sampled different sectors of the electro-magnetic and thermal spectra radiated back to space; and active sensors that through pulses of energy could determine not only distances between the satellites and Earth which allowed topographic features to be mapped based upon precise knowledge of the ephemeris of the satellite, but other parameters of the natural environment that determined *how* energy was scattered back to the sensor and not just the time it took for

[129] MEDEA Special Task Force, *Scientific Utility of Naval Environmental Data* (McLeam: Mitre Corporation, 1995).

the round trip. In essence a whole new world was visible to remote sensors, devices that could be flown on aircraft to resolve some features of interest, but that when flown is space – above any notions of international boundaries to which aircraft were required to conform – provided coverage that was unachievable in any other fashion. With time these synoptic observations provided new views on climatology, and a greater appreciation for how man impacted his environment both through emissions of greenhouse gases and through land use changes that affected atmospheric and oceanic processes observable from space. Systems and sensors now on orbit monitor a broad variety of environmental variables including "…the evolution and impact of El Niño, weather phenomena, natural hazards, and extreme events such as floods and droughts, vegetation cycles, the ozone hole, solar fluctuations, changes in snow cover, sea and ice sheets, ocean surface temperatures and biological activity, coastal zones and algal blooms, deforestation, forest fires, urban development, volcanic activity, tectonic plate motion, and others."[130] Although often thought of generically as "remote sensing satellites," it is important to note that not all satellites are the same; specific sensor instruments are required for sampling different environmental parameters. Choices must be made in funding enormously expensive satellite missions and the research and development of sensor instruments…choices that are influenced both by scientific interest in particular environmental variables, but also -historically and importantly - by military necessity.

Virtually all satellite sensors that measure ocean variables or the atmospheric parameters that influence ocean dynamics could be discussed at length for their concurrent military and scientific utility. For either the direct information that they provide or from products that are derived from their data, remote sensing satellites have become integral to naval operations. For present purposes in discussing 21st Century naval challenges involving both traditional military threats such as those that are posed by submarines and less conventional threats such as the potential for global climate change to impact security interests, one particular sensor stands out: the satellite altimeter. After three earlier missions proved the utility of satellite altimetry to naval operations through the ability of the sensor to measure sea surface topography deviations that provided information about local variations in gravity, the United States Navy launched the Geodetic/Geophysical Satellite (GEOSAT) into orbit in 1985. GEOSAT's primary mission dataset was

[130] Committee on Earth Observation Satellites, "Earth Observation Handbook," 2005 (accessed May 04, 2006); available from http://www.eohandbook.com/eohb05/.

(originally) classified, but intended to serve navigational and mapping requirements for the Navy. One open-source description of this mission fills in the rough parameters, "Consider measuring accelerations in a moving submarine or aircraft in order to determine your position as a function of time (of course your starting position and velocity must also be known)...[without other references]…a true acceleration cannot be distinguished from a variation of the pull of gravity. Thus the gravity data are needed for correction of inertial navigational/guidance systems."[131] Gravitational attraction between two objects varies with mass, something we usually don't account for ourselves in common use since the Earth is so massive as compared to objects within everyday human frames of reference; similarly in everyday use we do not have to consider variations in gravity, but they exist on large scales and both of these considerations must be taken into account from a military perspective with respect to submarine (and aerial) inertial navigation as well as inertial guidance systems for intercontinental ballistic missiles.[132]

The surface of the ocean is relatively level – something that might be argued by sailors who regularly see vertical excursions at a scale large to them – and the theoretical surface of an ocean at rest describes an equipotential gravitational surface known as the geoid, an ellipsoid that at first approximation "corresponds to the surface of a rotating, homogenous fluid in solid-body rotation…[but that]…differs…because of local variations in gravity…called geoid undulations." Gravitational variations arise due to the proximity and structure of seafloor features such as seamounts or submarine trenches; since the sea surface must everywhere be perpendicular to the pull of gravity, bulges and depressions are formed on its face in the vicinity of these subsurface features. Seafloor bathymetry can cause the sea surface height to vary by one to twenty meters over a few hundred kilometers; at the extreme geoid undulations as much as sixty meters can result from seafloor geomorphology. But the sea surface does not correspond exactly to the geoid; dynamic influences on sea level as a result of ocean currents and tides cause additional sea surface topographic deviations from the geoid generally on the order of about ten centimeters to one meter at their

[131] David T. Sandwell and Walter H.F. Smith, "Exploring the Ocean Basins with Satellite Altimeter Data," 1997 (accessed June 25, 2006); available from http://topex.ucsd.edu/marine_grav/explore_grav.html.
[132] Gary M. Mineart, Morton D. Rau, and Jay L. Finkelstein, "An Examination of U.S. Plans for Meeting Operational Ocean Observation Needs with Radar Altimetry," in *MTS/IEEE Oceans 2004* (Kobe: Institute for Electrical and Electronic Engineers, 2004).

largest, but they are small compared to geoid undulations.[133] Therefore, by accurately measuring sea surface topography from space with an altimeter such as the one flown aboard GEOSAT, a close approximation of the marine geoid can be determined; from this approximation, gravitational variations can be mapped throughout the oceans for use in subsurface inertial navigation and for ballistic missile guidance systems.

While they were flown for the important national security considerations described above, satellite altimeters quickly proved their use for other investigations applicable to naval operations – and as always to civilian scientific pursuits that differed only in their perspective. Since the mapping of the marine geoid necessarily made assumptions about seafloor influences on geoid undulations, satellite altimeters were essentially capable of mapping the seafloor. This theoretical leap required significant ground truth from acoustic measurements of the depth of the ocean because of numerous simplifications to geomorphological variability implied in such a technique; altimetric measurements provided the data to interpolate between *in situ* measurements by ship transducers. Satellite altimeters consequently allowed the first comprehensive charts of the seafloor to be made to approximately one hundred meter depth resolution, revealing all major ocean structures greater than fifteen kilometers in horizontal extent between 72° north and south latitudes (eventually to approximately 80°north and south with the addition of data gathered later by European satellites). Even with advanced acoustic survey tools, it is estimated that 125 ship-years of survey would be required to produce a complete bathymetric chart of the oceans.[134] Critical as this information was to naval operations, the utility of satellite altimeters was only beginning to be understood by scientists and naval oceanographers. In addition to proving their ability to detect subsurface features and providing the justification for flying the dedicated GEOSAT mission to measuring the marine geoid, altimetric sensors flown on Skylab, GEOS-3, and SEASAT in the 1970s demonstrated their use for tracking variable mesoscale (on the order of 100 kilometers) features such as ocean eddies that shed from ocean currents and that were generated along coastlines and propagated offshore.

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[133] Robert H. Stewart, "Introduction to Physical Oceanography," January 19, 2005 (accessed July 23, 2006); available from http://oceanworld.tamu.edu/resources/ocng_textbook/chapter03/chapter03_04.htm.
[134] Sandwell and Smith, "Exploring the Ocean Basins with Satellite Altimeter Data," (accessed); Stewart, "Introduction to Physical Oceanography," (accessed).

Determination of the marine geoid required repeated passes over the ocean to remove the variability of surface waves and other time-dependent features including tides; but sometimes the signal is in the noise…and the variability that was noise in determining the geoid could be measured to investigate temporal features such as ocean eddies as they propagated through the oceans. Depending on the resolution of the sensor and the repeatability of the ground track, features could be resolved at different timescales and of various dimensions; with enough coverage in both time and space, features down to mesoscale parameters and even smaller could be accurately followed throughout the oceans. Once GEOSAT completed its classified mission, its orbit was altered to place it in a 17-day Exact Repeat Mission (ERM); circling the globe approximately fourteen times per day the satellite provided repeat coverage of ocean areas approximately twice per month.[135]

As discussed earlier, the thermal and saline structure of mesoscale ocean features was important acoustically and made them the subject of interest for antisubmarine warfare. In its ERM orbit, GEOSAT allowed the location and tracking of such mesoscale features, and because a satellite altimeter is an active microwave sensor it was able to do so irrespective of cloud cover that obscured the thermal signature of some of these features from infrared radiometers, a factor that was important in areas such as the GIUK Gap. In addition, altimeters were capable of determining sea state as a result of the backscatter of the microwave energy beamed to the ocean surface and reflected variably back to the sensor according to the surface roughness which correlated to the height of ocean waves; wind speeds at the surface could be implied from this same technique.[136] These were important parameters for antisubmarine warfare because of the acoustic clutter that high seas created, but they were also important for the safe and efficient routing of surface vessels in areas of high winds and seas. This was an obvious way to avoid topside damage, but structural hull damage was also possible with heavy pounding in high seas; what is more fuel economy was always an important consideration both for the costs of fuel as well as the difficulty and inconvenience of refueling vessels at sea.

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135 David L. Porter, Scott M. Glenn, Ella B. Dobson, and Allan R. Robinson, "GEOSAT: A U.S. Navy Spaceborne Altimeter," *Oceanus* 33, no. 4 (1990/1991); Sandwell and Smith, "Exploring the Ocean Basins with Satellite Altimeter Data," (accessed).
136 Committee on Earth Observation Satellites, "Earth Observation Handbook," (accessed).

Sea surface observations by environmental remote sensing satellites provide measurements of many parameters of direct interest to naval operations, but only some of these measurements can reliably extrapolated to infer ocean structure in three dimensions. Infrared radiometers detect sea surface temperatures and can identify specific ocean features such as warm and cold core eddies or current boundaries by their thermal signatures, but radiometric measurements sample only the very surface of the sea; to be sure these thermal features extend to varying depths, but can do so in a way that is very complicated by local influences and extensive climatologies are required to make these theoretical leaps in anything but rudimentary fashion. Multispectral imagers can often detect physical ocean features such as currents or eddies from the patterns of ocean color created by distributions of plankton; but again these are surface images and not ones that imply information to depth other than through known relationships studied *in situ* that allow the inference of these localized features below their surface depictions.[137] Satellite altimeters on the other hand provide information that can be reliably extrapolated to depth even in areas without extensive *in situ* studies because of the ocean physics behind the sea surface features that they measure – although logically with *in situ* knowledge much more can be inferred.

Mesoscale elevations and depressions of the sea surface result as a dynamic balance of forces known as geostrophy. Horizontal pressure gradient forces arise from differences in density that result from temperature and salinity patterns; these forces set currents in motion that when acted upon by planetary Coriolis forces become orthogonal to the pressure gradient. In other words, analogous to the manner in which areas of atmospheric high and low pressure determine the direction and intensity of winds, density anomalies in the ocean - areas of high and low sea surface heights - determine dynamically the location of geostrophic ocean currents, and the sea surface gradients between these features describes the pressure gradient which controls current intensity. Warm water features form bulges on the sea surface that depress the thermocline at depth, while colder features create sea surface depressions with a subsurface structure that can extend much deeper in the water column, even to the bottom.

[137] William B. McQueary, "R&D Required for Remote Sensing," *Sea Technology* 35, no. 11 (1994): 53-55.

The surface height differences described above are known as steric height anomalies which imply they are thermohaline in nature as opposed to changes in sea surface height that can occur with the addition of fresh water from continental sources and that are known as eustatic changes. Steric signatures particularly are apparent in eddies that shed from current systems such as the Gulf Stream in the Atlantic, the Kuroshio in the Pacific, and the loop Current in the Gulf of Mexico, but sea surface elevations also describe warm and cold currents themselves instead of only the closed circulations that spin off of them: the difference in sea surface height measured across the expanse of one of the more prominent of these features, the Gulf Stream in the North Atlantic, is roughly one meter. As mentioned above, infrared radiometers are often capable of identifying dynamic ocean features by their thermal signatures, but this is not always the case. In cloudy areas, the ocean signal is obscured from the passive radiometers by colder cloud tops while sea surface height remains observable by active microwave altimeters, but this is not the only reason altimeters provide unique information for the study of mesoscale ocean features. With time, diffusion and mechanical mixing diminishes the surface temperature gradient visible to satellite radiometers and when features such as cold core eddies sink, their thermal signatures can become entirely obscured even while they remain detectable through sea surface topographic measurements from satellite altimeters.[138]

Because of their ability to detect ocean features important to both the thermal structure of the ocean and to ocean currents, satellite altimeters have become important contributors to modeling efforts to describe and to eventually forecast them. While these models are important to scientists doing general research on the oceans and applied research into areas such as climate change, they are particularly important to naval oceanographers in describing the ocean as a matter of undersea warfare. The ocean is roughly stratified with warmer water generally lying above colder water and a transition region known as the thermocline marking the strongest gradient between the two. Regional anomalies in sea surface height affect the depth of the thermocline because of pressure variation felt throughout the water column. Since sound waves refract towards areas of lower sound velocity, the location and strength of the thermocline is critical for undersea warfare; the path that sound travels will vary between the route it takes through the relatively homogenous zone of the mixed layer above the thermocline to the region below where density effects that

[138] Brown, Colling, Park, Phillips, Rothery, and Wright, *Ocean Circulation*, 108-112; David Tolmazin, *Elements of Dynamic Oceanography* (Boston: Allen & Unwin Inc., 1985), 105-111.

are associated with increasing pressure eventually take control, and “shadow zones” of non-coverage may result. Of particular importance to modelers seeking to characterize the ocean and these effects are the dimensions of such regional features, “Open ocean dynamics generating the sea level changes are mainly mesoscale eddies and current meanders.”[139] The size and variability of these ocean phenomena can be difficult to resolve by methods other than remote sensing, “The length and time scales of these processes are too large for conventional in-the-water oceanographic instrumentation configurations to measure sea surface topography. The shape of the sea surface is the only physical variable directly measurable from space that is directly and simply connected to the large-scale movement of water and the total mass and volume of the ocean.”[140]

The U.S. Navy uses long-term climatological models such as the Generalized Digital Environmental Model (GDEM) to characterize an area of the ocean where naval forces are operating if more up to date information is not available. GDEM provides temperature, salinity, and sound speed profiles at half-degree resolution that are mathematically optimized for time and place from a database of over seven million observations. Unless mesoscale features are seasonally present and relatively consistent, such a database will miss their presence when characterizing the ocean for a naval operation that takes place at a particular time and location. In order to improve upon this sort of climatology, real time data is collected and used to initialize models by locating features within model surfaces – “biasing” a model – and allowing the model to then develop the feature with time. This may be done with *in situ* data taken by expendable bathythermograph (XBT) or with conductivity-temperature-depth meters (CTDs), but while these are “ground truth” they are methods with both spatial and temporal limitations that may not completely characterize the water masses of a highly dynamic region. The way that synoptic coverage is achieved for initializing model runs is by assimilating sea surface temperature (SST) measurements taken by satellite radiometers and sea surface height (SSH) measurements from satellite altimeters; remote sensors thus provide both initial sea surface boundary conditions to bias model runs and the follow-on observations necessary to validate model performance. The Modular Ocean Data Assimilation System (MODAS) is the

[139] G.A. Jacobs, C.N. Barron, D.N. Fox, K.R. Whitmer, S. Klingenberger, D. May, and J.P. Blaha, "Operational Altimeter Sea Level Products," *Oceanography* 15, no. 1 (2002).
[140] "Geosat Follow-On [GFO]," *Military Space Programs*, 2000 (accessed June 25, 2006); available from http://www.fas.org/spp/military/program/met/gfo.htm.

U.S. Navy's state of the art program suite to generate nowcasts and forecasts of ocean parameters by merging satellite derived data with climatology to characterize the ocean battlespace. [141]

MODAS is a collection of more than one hundred programs that "…acquire and quality control input data of various types (including satellite remote sensed information); use satellite data to refine climatological temperature and salinity in the oceans; merge *in situ* measurements with a "first guess" field to produce a "best guess" of the present conditions in the ocean; and provide a short-term forecast of the ocean, including currents and tides."[142] MODAS improves upon climatology when characterizing the ocean by using *in situ* or remotely sensed data to create a "dynamic climatology" that rather than assigning an average temperature-salinity profile for the area from a historical database, computes a more appropriate one from relationships derived using local historical data which correlate structure to depth with observed conditions at the sea surface. A "synthetic" dynamic profile of temperature and salinity variation with depth is the result. More than two and one-half million temperature profiles and almost one million salinity profiles from one hundred years of data are used to establish the mathematical regressions which pair surface height and temperature data to subsurface temperature-salinity profiles. MODAS then can be used to characterize sound velocity fields for direct employment by naval platforms engaged in undersea warfare.[143]

The first step in this process is to establish fields that adequately describe the temperature and sea surface height variance of the ocean surface above the area of interest that can later be projected to depth to infer temperature and salinity parameters according to the previously described regressions. Satellite data – as extensive as it is compared to data collected *in situ* – does not provide uniform coverage, so depicting this ocean battlespace becomes a computationally intensive process. Sea surface temperature can be obtained over relatively broad areas through Multi Channel Sea Surface Temperature (MCSST) analysis of data collected by satellite radiometers on a series of polar orbiting satellites. These sensors collect data

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[141] Peter C. Chu, Michael D. Perry, Eric L. Gottshall, and David S. Cwalina, "Satellite Data Assimilation for Improvment of Naval Undersea Capability," *Marine Technology Society Journal* 38, no. 1 (2004).
[142] "MODAS," June 23, 2003 (accessed June 28, 2006); available from http://www7320.nrlssc.navy.mil/modas/.
[143] "MODAS: Dynamic Climatology," June 03, 2003 (accessed June 28, 2006); available from http://www7320.nrlssc.navy.mil/modas/climatology.html.

across hundreds of miles in a single pass, although gaps in SST coverage may exist over areas of interest because of incomplete and periodic coverage from polar orbits and from periods during which clouds obscure the sea surface from the radiometer.

The altimeter data used to determine sea surface height is comparably sparse and only available over relatively narrow swaths of a few miles along satellite ground tracks for any given sampling period; since the spacing of ground tracks and revisit times vary considerably by satellite platform and instrument, signals that would identify mesoscale features of importance may easily be lost within data-sparse regions. Even if detected by one satellite altimeter pass, features are not stationary and can propagate away in the number of days before satellites revisit the area - demonstrating the dependence of mesoscale sea surface height studies on adequate altimetric coverage, "Ocean eddies generally have length scales from 20 to 100 km. Providing a synoptic picture of the ocean eddy field would not be possible using only the data of a single altimeter satellite and is only marginally possible with three."[144] Therefore, while data from both radiometers and altimeters must be optimally interpolated to "fill in" the data gaps that exist between satellite ground tracks this is an especially critical procedure for the altimeter data.

New altimeter observations along ground tracks are subtracted from the MODAS "first guess" weighted average of the previous 35 days of data, and differences determined in these narrow bands are optimally interpolated with mathematical covariance functions that describe how anomalies at one place in space and time relate to others throughout the dataset. This produces a two-dimensional deviation field which is then added back to the "first guess" average of the previous month's worth of data to generate the new two-dimensional sea surface height field, which itself is depicted as an anomaly from a MODAS climatological mean steric height. This becomes very important when characterizing a new location, "For the first iteration of the optimal interpolation, climatology is used for SST and the SSH measurement is assumed to have a zero deviation [from the climatological mean steric height anomaly]. This means that until the field

[144] Jacobs, Barron, Fox, Whitmer, Klingenberger, May, and Blaha, "Operational Altimeter Sea Level Products," 17.

deviates from the climatology, the extra data has no added value and MODAS reverts to climatology."[145] Without satellite altimetry data, MODAS becomes little more than a program suite operating with the GDEM database, providing the warfighter with only historical information in areas where dynamic features may dominate the ocean battlespace.

Depending upon the particular location in the oceans and the presence of features which affect acoustic propagation, availability of satellite altimetric data may make a critical difference in undersea warfare scenarios. To examine this possibility, a study was conducted to examine such a situation with respect to acoustic presets to weapons systems, in this case the U.S. Navy's Mark 48 torpedo. Weapons presets provide for improved performance based upon the environmental parameters that influence underwater acoustic propagation and are determined by projections for the probability of detection of underwater adversaries together with the likelihood for effective prosecution under ambient conditions. The area selected for the study was a dynamic region of the North Atlantic that transected the Gulf Stream because of the expected variance that would be encountered between historical GDEM fields and near-real time MODAS fields that benefited from the ingest of remotely sensed satellite data. Ocean variability often induces 'range-dependent' acoustic scenarios with decreased detection probabilities that result from the refraction of sound across temperature and salinity (density) gradients. In this instance the study data showed that sensor/weapon performance would have been better than expected because the particular combinations of temperature and salinity throughout the water column – while variable across the field and with additional complications provided by the presence of mesoscale eddies – produced sound speed profiles that enabled better coverage, "…an unrealistic expectation in the weapons effectiveness would have resulted from the use of GDEM data to predict the coverage percentages in the water column. The MODAS data would have given the user the freedom to operate anywhere in the region knowing that their weapon would function about the same no matter the location."[146]

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145 Chu, Perry, Gottshall, and Cwalina, "Satellite Data Assimilation for Improvment of Naval Undersea Capability," 12.
146 Ibid.: 22.

Estimations such as these are critical to naval planning; the range of effective passive and active sonar coverage is essential to determining how long and with how many assets it will be necessary to “sanitize” an area to ensure that enemy submarines can not gain access to high value targets. “Blue force” losses are estimated given the uncertainty associated with enemy submarine locations and the probability that they will close friendly forces and sink at least some shipping before they are defeated. To ensure required combat power to achieve operational goals, enough forces must be dispatched to absorb these losses and still complete the mission. Entire warfighting strategies hinge on the phased movement of forces, the protection of those forces in the area of operations and the employment of sea-based logistics to sustain forward combat elements. The maintenance of sea lines of communications (SLOCs) and protected areas of operations and resupply positions depends upon confidence in characterization of the undersea warfare picture. While the use of satellite remote sensed data may seem academic to the researcher attempting to study an ocean feature or patterns that might say something about climate change, to naval operations this data may make the difference between winning or losing a campaign, not to mention what it means to protecting valuable warships and their crews.

With direct application to antisubmarine warfare, MODAS fields derived from satellite data are of obvious importance to naval operations. But ASW is not the only area of naval warfare that utilizes modeled ocean data. The Navy’s increased emphasis on operations in the littorals means that forces will operate in areas that *in situ* data may be problematic to collect; information such as tides, coastal currents and wave height are particularly important. Consequently amphibious warfare, special operations, mine countermeasures, and logistics support – in addition to antisubmarine warfare in littoral environments already described at some length – will depend on remotely sensed data and numerical modeling to describe and forecast parameters of interest to their safe and effective execution.[147] Coastal models can ingest remotely sensed data directly, but they are also dependent upon high resolution open ocean models to initialize their seaward boundary conditions which “…can influence the littoral environment by driving a flux of mass, heat, or a biological variable across the continental shelf break.”[148] Satellite remotely-sensed

[147] Ibid.: 13; McQueary, "R&D Required for Remote Sensing," 53.
[148] McQueary, "R&D Required for Remote Sensing," 57.

data fields are used operationally to initialize numerical ocean models of increasing resolution that extend from the open ocean into littoral areas important to naval operations.

The Naval Research Laboratory Layered Ocean Model (NLOM) is run daily for open ocean areas up to the 200 meter isobath at 1/32° resolution using atmospheric forcing (heat and momentum fluxes) from the Navy Operational Global Atmospheric Prediction System (NOGAPS), sea surface temperature from satellite radiometers, and sea surface height information from satellite altimetry. NLOM utilizes an optimization technique similar to MODAS for ingesting altimetric data and the MODAS optimizations of SST to initialize sea surface fields to produce fifteen to thirty day ocean front, eddy and sea surface height forecasts. When NLOM fields are run through the MODAS program suite, this enables MODAS forecasts of three dimensional temperature, salinity and current fields on similar timeframes at one-quarter the grid resolution. Using the three dimensional temperature and salinity fields from MODAS and the heat and momentum fluxes from NOGAPS, the Naval Research Laboratory's Coastal Ocean Model (NCOM) is then run at 1/8° resolution over areas of interest worldwide.

A Shallow Water Analysis and Forecast System (SWAFS) model also depends on assimilated satellite SSTs and SSH as well as data collected *in situ* and tidal information from global tide models to produce "nested" models of increasing resolution from 1/4° down to seven kilometers over specific ocean basins, and to two kilometers over even smaller regions. This data is especially vital for nearshore amphibious operations, special operations, and mine warfare. SWAFS provides trajectory drift information for objects such as floating mines and can be used to estimate oil spill trajectories from accidental – or intentional – discharges of oil that are important not only for their environmental damage but for the fouling of desalination plants and other socioeconomic impacts as well as affecting naval operations in the vicinity. Wave Action Models (WAMs) are run to provide predictions of wave direction; significant wave height (a term that describes the predominant wave height in a variable field); swell direction, period and height; wind wave height; and average wave period. WAMs rely on surface wind forcing from NOGAPS, and from the Coupled Ocean Air Meteorological Prediction System (COAMPS) which also relies on satellite

ingest to provide initializing sea surface conditions.[149] Sea surface temperature from satellite radiometers and sea surface height, wave height and wind speed as derived from satellite altimeters are therefore critical to virtually all naval operational modeling efforts.

The utility of remotely sensed altimetric data is dependent upon the accuracy of the satellite system as well as the availability of adequate coverage over areas of interest to naval operations…or scientific interest. Bouncing a microwave off of the ocean's surface in order to measure the round trip time and parameters of the return pulse does not seem – in comparison to some other technological marvels of the 21st Century - like a very sophisticated scientific measurement to make, or one that would require a particularly complex sensor to conduct. Yet to achieve the accuracies necessary to measure geophysical variables of interest these assumptions are simplistic, "In order for an altimeter to efficiently and accurately sample mesoscale features, there are several requirements placed on its accuracy, orbit and period. A satellite altimeter must produce measurements that are accurate to within 5cm, or the errors that propagate down into the temperature and salinity calculations will be unacceptable. With an error of only 5 cm, the error in the temperature calculation can be 1-2° C."[150] From orbits hundreds of miles above the Earth, the altimeter is expected to detect changes on the order of 1-2 inches – the equivalent of "…sensing the thickness of a dime from a jet flying at 35,000 feet."[151] Such precision is not required for all ocean parameters that might be studied, but obviously the more exact the measurement the better the data and the more accurate the measurable *differences* between repeat observations.

Operating at high frequencies, altimeters transmit over 1700 pulses per second to Earth; it is by averaging this extremely high number of pulses which allows for removal of effects such as stronger signal

[149] "COAMPS Overview," (accessed August 07, 2006); available from http://www.nrlmry.navy.mil/coamps-web/web/view; Steve Haeger, "Data Assimilation for Operational Models," September, 2003 (accessed June 28, 2006); available from http://www.atmos.umd.edu/~carton/dameeting/pdfs/haeger.pdf; Robert C. Rhodes, Charlie N. Barron, Dan N. Fox, and Lucy F. Smedstad, "Real-time Assimilation of Altimeter Derived Synthetic Profiles Into a Global Version of the Naval Research Laboratory's Coastal Ocean Model (NCOM)," 2001 (accessed June 28, 2006); available from http://www.7320.nrlssc.navy.mil/fall_agu_2001/talks/rhodes.pdf.
[150] Chu, Perry, Gottshall, and Cwalina, "Satellite Data Assimilation for Improvment of Naval Undersea Capability," 13.
[151] "Changing Climates: The Ocean Connection," July, 2001 (accessed August 4, 2006); available from http://www.jpl.nasa.gov/earth.

returns from wave troughs than from wave crests in measuring the sea surface. These microwave pulses must also be corrected for transmission effects due to water vapor (wet and dry tropospheric corrections) and ionization in the atmosphere which account for up to two centimeters of instrument precision error; to diminish errors and to facilitate these corrections, some altimeters operate at dual frequencies for signal comparison and some carry instruments that make necessary concurrent measurements of relevant atmospheric parameters.[152] Precise orbit determination (POD) is the most important source of altimeter error; various methods are employed to pinpoint the satellite's position above a reference ellipsoid, including Global Positioning System (GPS) receivers which can track up to six GPS satellites at one time; the Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) system which utilizes 50 ground stations to detect shifts in reference microwave signals to determine precise orbits; and passive retroreflector arrays which return laser energy beamed from some twenty satellite laser ranging (SLR) stations around the world. Satellite tracking information from these methods is combined with models that estimate gravity effects and aerodynamic drag (which varies with orbital height) to determine satellite ephemeris information within about three centimeters…or a little more than one inch.[153] Ideally a satellite would carry all three positioning technologies; given expense (not just of the instrument but of the entire ground support structure for the various methodologies) and weight considerations aboard a satellite, this may appear overly redundant, but failure to achieve POD is failure of mission: GPS receiver failure onboard the GEOSAT Follow-On (GFO) satellite in 1998 would have meant the end of mission if not for a redundant SLR array which allowed for POD and ultimately mission continuance.[154]

Because remote observation of mesoscale ocean activity requires observation of time-varying features over ranges on the order of twenty to one hundred kilometers, selection of satellite orbital heights and orbital trajectories is critical to which features may be studied. The specific design parameters of the altimeter sensor determine the swath of usable data at nadir, but the combination of these two orbital

[152] "How Altimetry Works," 2006 (accessed August 04, 2006); available from http://www.jason.oceanobs.com/html/alti/principe_uk.html; Jacobs, Barron, Fox, Whitmer, Klingenberger, May, and Blaha, "Operational Altimeter Sea Level Products."
[153] Margaret Srinivasan, "Ocean Surface Topography from Space: Technology," September 22, 2005 (accessed August 04, 2006); available from http://sealevel.jpl.nasa.gov/technology/technology.html.
[154] Mineart, Rau, and Finkelstein, "An Examination of U.S. Plans for Meeting Operational Ocean Observation Needs with Radar Altimetry," 1800.

factors determines the overall latitudinal coverage and ground spacing of satellite observations for specific missions, as well as the crossover geometry of ground tracks for comparison of measurements taken earlier by the same satellite or for cross-comparison of data collected by other altimeters on orbit. Crossover orthogonality for same-satellite ascending and descending orbits or for cross-comparison between satellite missions that overfly the same area is important for orbit corrections as well as defining three dimensional ocean topology.[155] The root mean square (rms) difference of same-satellite orbital crossover data is a measure of overall satellite accuracy; comparing rms crossover noise between different satellite missions demonstrates differences in their accuracies as well as in the calculations that determine their orbital or sensor corrections. Sea surface height anomalies measured at satellite crossover points can be affected by the time between measurements which might alias dynamic ocean signals, but despite this concern "…provides a good measure of the overall system accuracy, which includes accuracy of all atmospheric corrections, orbit solutions, tide solutions, and mean sea levels added together."[156]

The earliest altimeters aboard SKYLAB and GEOS-3 were proof of concept sensors that determined the feasibility of measuring the marine geoid with altimeters over very limited areas. When it was launched in 1978, the subsequent SEASAT mission was placed in an orbit that allowed higher latitude observations to more completely map the marine geoid, but was additionally the first satellite intended to also measure variable ocean features of interest. SEASAT failed after only 100 days, but was a spectacular success for the data it provided and paved the way for future missions.[157] The U.S. Navy's GEOSAT mission seven years later was placed in essentially the same orbit as SEASAT and allowed for observations north and south as high as 72° latitude; the GFO provides repeat coverage of earlier GEOSAT ground profiles within plus or minus one kilometer. In the Exact Repeat Mission (ERM) phase of its mission, GEOSAT provided (and GFO provides) seventeen day repeat observations with ground track separation at the equator of 164 kilometers and made available to the research community "…the first long term global observations of sea

[155] Ibid.
[156] Jacobs, Barron, Fox, Whitmer, Klingenberger, May, and Blaha, "Operational Altimeter Sea Level Products," 17.
[157] Robert Stewart and Michael Lefebvre, "History of Altimetry, 1960-1992," in *15 Years of Progress in Radar Altimetry* (Venice: European Space Agency, 2006).

level, wind speed, wave height, and ice topography."[158] Inaccuracies in GEOSAT precise orbit determination made for considerable errors in the data provided during mission life, but recomputation of satellite emphemeris and improved gravity models has allowed the reanalysis of GEOSAT data with about ten centimeter accuracy – not enough to capture all mesoscale variability of interest, but still useful for the study of ocean phenomena.[159] With improved orbital determination and models that determine atmospheric corrections, the GFO mission achieves rms crossover accuracies on the order of 7.7 centimeters.[160]

The joint National Aeronautics and Space Administration (NASA) – Center National des Etudes Espatial (CNES) Topographic Experiment (TOPEX)/Positioning Ocean Solid Earth Ice Dynamics Orbiting Navigator (POSEIDON) satellite mission was designed with an orbit that placed it almost twice as high as GEOSAT and GFO but with an inclination that did not approach as close to the poles; this tradeoff provided for shorter repeat periods of approximately ten days but greater track separation at the equator of some 315 kilometers. Improved POD and satellite design provide for smaller measurement errors and TOPEX/POSEIDON demonstrated 5.1 centimeter rms altimeter crossover difference accuracy – the first satellite able to sample mesoscale ocean variability with that precision.[161] Launched in 1992, TOPEX/POSEIDON was intended to be a three-year mission to provide global observations of the world's oceans, improve understanding of ocean currents, and improve forecasting of global climate; when it failed in January 2006, TOPEX/POSEIDON had provided almost thirteen and one-half years of data on the world's oceans including critical observations of the 1997 El Niño and 1999 La Niña events that affected weather patterns around the world. The NASA-CNES follow-on mission to TOEX/POSEIDON, the Joint Altimetry Satellite Oceanography Network (JASON) mission was launched in 2001 into a TOPEX/POSEIDON orbit with essentially the same sensor suite and mission accuracy, and continues to

[158] John Pike, "Geosat," *Military Space Programs*, 1997 (accessed July 10, 2006); available from http://www.fas.org/spp/military/program/met/geosat.htm.
[159] "The Geosat Altimeter JGM-3 GDRs on CD-ROM," May, 1997 (accessed July 10, 2006); available from http://www.grdl.noaa.gov/SAT/gdrs/gesoat_handbook/.
[160] "Geosat Follow-On [GFO]," (accessed); Jacobs, Barron, Fox, Whitmer, Klingenberger, May, and Blaha, "Operational Altimeter Sea Level Products."
[161] Jacobs, Barron, Fox, Whitmer, Klingenberger, May, and Blaha, "Operational Altimeter Sea Level Products."

provide data as of this writing.[162]

Even though satellite altimeters have flown at various times for some thirty years, and as many as five altimeters have flown at once, only about half of that time have sensors been on orbit with the requisite accuracy and mission profiles to have proved particularly applicable for the study of mesoscale ocean variability. A recent conference touting "15 Years of Progress in Radar Altimetry" highlights the fact that over this more limited time span a *continuous* series of high-fidelity data has been collected since the launches of the European Remote Sensing (ERS) series of satellites launched by the European Space Agency (ESA) and the joint TOPEX/POSEIDON mission by NASA of the United States and CNES of France. First launched in 1991, the ERS series of satellites were flown at approximately the same orbital height as GEOSAT, but with different inclinations that provide higher latitudinal coverage to 82° and closer equator ground track spacing of 80 kilometers, and with a longer exact repeat track periodicity of 35 days. ERS rms crossover accuracy of 8.8 centimeters placed this data between GEOSAT and GFO in precision.[163] ERS-1 flew from July 1991 through September 1995 and ERS-2 provided useful data from August 1995 through June 2003, when onboard recorder failures prompted ESA to shift duties to its follow-on satellite ENVISAT which was launched in March 2002 and remains on an ERS-style orbit providing comparable data.

Prior to late 1991 almost a two-year gap existed in satellite altimetry data after the degradation in late 1989 and outright failure of GEOSAT in 1990; with the known errors of the GEOSAT data, this mission was an excellent proof of concept for measuring ocean variability - and reanalysis now decades later has provided some useful information that extends the altimetry dataset more reliably - but is not placed in the same category of operational capability of the more recent missions. GEOSAT was also a solo mission, and from experience with more than one altimeter on orbit, ocean scientists have determined that multiple sensors in different orbits with repeated track crossovers are necessary to provide the spatial and temporal sampling coverage required to accurately resolve mesoscale ocean parameters and track them across ocean

[162] "TOPEX/Poseidon: Sails Off Into the Sunset," *Ocean Surface Topography from Space*, January, 2006 (accessed August 04, 2006); available from http://sealevel.jpl.nasa.gov/newsroom/features/200601-1.html.
[163] Jacobs, Barron, Fox, Whitmer, Klingenberger, May, and Blaha, "Operational Altimeter Sea Level Products," 17.

basins.[164] Different orbits help to also eliminate aliasing from tidal constituents or from ocean phenomena that vary on the same frequency as satellite revisit times. While missions that are flown on different orbits help to resolve temporal and spatial considerations, overlapping altimeter missions flown in similar orbits have their own benefits; they are particularly helpful to verify the accuracy of long term multiple-sensor datasets, allowing direct comparison of data between "old" and "new" missions before failure of the sensor instrument or satellite bus occurs. While noted earlier that up to five altimeters flew contemporaneously for a short period (ERS-2, GFO, TOPEX/POSEIDON and JASON were all on orbit when ENVISAT was launched in December 2002), two of these satellites were replacement missions that flew essentially the same orbits as their predecessors and provided important verification about follow-on sensor performance but only limited additional temporal and spatial coverage from the altimeter constellation.

Recognizing the limitations of altimetric datasets, various technologies and mission profiles have been proposed that would both improve spatial and temporal coverage as well as the type of data gathered for specific applications. For various reasons, these proposals to date have met with budgetary constraints or physical catastrophe leaving the scientific goals of the missions – and the scientists who propose them - frustrated. Besides the obvious benefits of more altimeter missions and varied mission profiles that improve temporal and spatial coverage, improvement of altimetric data collection focuses around increasing the capabilities of the sensor itself. In this regard, two technologies have dominated the discussion: wide swath synthetic aperture altimetry and delayed Doppler altimetry.

The first of these proposed techniques, Wide Swath Ocean Altimetry (WSOA), relies on multiple instruments flying onboard a single satellite. A conventional pulse limited altimeter would provide a traditional nadir view of the sea surface, while offset sensors would use this nadir looking altimeter as a reference to provide interferometric views by beaming microwave energy obliquely that is spread across a wide swath and received by the alternate interferometric sensor. In this fashion three swaths could be

[164] P.D. Cotton and Yves Menard, "The Future Role of Satellite Altimetry - Early Recommendations from the GAMBLE Project," 2003 (accessed June 25, 2006); available from http://www.altimetrie.net/documents.shtml; Jacobs, Barron, Fox, Whitmer, Klingenberger, May, and Blaha, "Operational Altimeter Sea Level Products."; Mineart, Rau, and Finkelstein, "An Examination of U.S. Plans for Meeting Operational Ocean Observation Needs with Radar Altimetry."

viewed beneath the satellite: a nadir view that is approximately two kilometers wide directly beneath the satellite with about 4.5cm accuracy, and on either side of this track beginning about fifteen kilometers from nadir and extending out to one hundred kilometers a lower resolution swath with 5.2 cm accuracy in the near field and 6.5 cm accuracy at the far range. Data would be mosaicked to average measurements over fifteen kilometer resolution cells, which would allow measurement of the sea surface gradient between pixels and consequently provide near-real time measurements of sea surface geostrophic velocity. Another advantage of the WSOA would be improved data collection near coastlines where conventional altimeters suffer data loss because of waveform leading edge tracking; this would provide greater sea surface height coverage to initialize coastal ocean models. Proposed as a demonstration on the JASON-2 Ocean Surface Topography Mission (OSTM) in 2008, the WSOA sensor on an almost ten day exact repeat cycle would provide mesoscale coverage of four to five comparable altimeter missions. Because of budgetary constraints the WSOA project was deleted from the JASON-2 OSTM mission in October 2005.[165]

The second technology that promises to enhance satellite altimetric data gathering is based upon a different principle for improving along track data resolution and signal to noise ratio: measuring the Doppler shift of the altimeter signal. With more efficient signal processing, the Delay Doppler Altimeter (DDA) halves the error of conventional pulse limited altimeters and improves along-track resolution by providing for higher pulse repetition frequencies. DDA is less sensitive to errors from ocean waves, and wind speed and wave height measurements are twice as sensitive as those obtained by conventional altimeters. Like WSOA techniques, DDA sensors would also improve coastal measurements as they do not suffer the same degradation of signal as conventional altimeters while making the transition from sea surface to land topographies. Because of this transition capability, the DDA was originally proposed for studying continental ice sheets and sea ice coverage, and a sensor was placed aboard the CRYOSAT satellite that was launched in October 2005 by the European Space Agency on a three-and-a-half year

[165] "Future Altimetry Missions: WSOA," 2006 (accessed August 07, 2006); available from http://www.jason.oceanobs.com/html/alti/wsoa_uk.html; S. Kaki, E. Rodriguez, and G.A. Jacobs, "Wide Swath Ocean Altimeter," October 13, 2004 (accessed August 07, 2006); available from http://eic.ipo.noaa.gov/IPOarchive/SCI/OOS_wsoapresentation.ppt; Pierrre-Yves Le Traon, "Altimetry and the Integrated Ocean Observing System," in *15 Years of Progress in Satellite Altimetry* (Venice: European Space Agency, 2006); Gary M. Mineart, *Emerging Space-Based Radar Altimeter Technologies* (Falls Church: Mitretek Systems, 2005), 10.

mission to determine variations in ice thickness to test predictions about the thinning of arctic ice as a result of global climate change. Unfortunately CRYOSAT never made it to orbit; it was lost on launch due to "an anomaly in the launch sequence."[166] Despite this setback, another application of DDA technology still held promise for ocean observations.

The determination of seafloor bathymetry from space was achieved as a result of the geodetic mission of the U.S. Navy's GEOSAT satellite mission. The release of the originally classified database was used to interpolate between *in situ* acoustic measurements to provide near-global seafloor coverage of features greater than fifteen kilometers in dimension.[167] While this proved orders of magnitude more accurate than earlier seafloor charts, scientists realized that even better resolution could be obtained…resolution that would be of use both operationally for naval applications as well as for additional areas of research relevant to both naval and civilian oceanographic interests. Improved resolution of seafloor bathymetry could be obtained by more refined measurement of the marine geoid…measurements that might be made by an advanced altimeter using Delay Doppler technology. Measurement of the marine geoid at higher resolution is itself worthwhile for improvements that could be made to naval inertial navigation and guidance systems, and higher resolution seafloor bathymetry - especially over coastal regions – is always a measurement with important naval considerations. As a bottom boundary condition, higher resolution bathymetry improves circulation and tide models; for submarine navigation high resolution bathymetry is important to both littoral operations – especially at a time when diesel submarines might again employ bottoming strategies to avoid pursuit – and to operations in the open ocean as well as was fearfully demonstrated in January 2005 when the attack submarine *USS San Francisco* rammed an uncharted Pacific seamount at high speed and narrowly avoided catastrophe.

A host of other benefits including improvements in tsunami forecasting, plate tectonics studies, submarine cable and pipeline planning, and boundary determination for Law of the Sea claims might also be accomplished with higher resolution bathymetric charts. By increasing the resolution of the altimetric

[166] "CRYOSAT," 2006 (accessed August 07, 2006); available from http://www.jason.oceanobs.com/html/missions/cryosat_uk.html; Mineart, *Emerging Space-Based Radar Altimeter Technologies*.
[167] Sandwell and Smith, "Exploring the Ocean Basins with Satellite Altimeter Data," (accessed).

sensor by a factor of two over GEOSAT and ERS through the use of a Delayed Doppler Altimeter, altering the mission profile to improve orthogonal crossover tracks in the mid-latitudes in order to better resolve east-west components of geoid slope, and extending the mission to six years to increase the number of measurements, scientists estimate that the proposed Altimetric BathymetrY from Surface Slopes (ABYSS) mission could improve gravimetric and bathymetric data by a factor of four to five and resolve more than 50,000 seamounts that currently remain uncharted. Another important goal of ABYSS would be the characterization of the seafloor roughness spectrum that determines variability in vertical ocean mixing as a result of interaction with tides and seafloor currents in order to investigate effects of such processes on climate. Similar dynamics influence nutrient mixing and transport which affect important fish stocks in the vicinity of seamounts and would be of important use to researchers as well as commercial fisheries.[168]

By designing a sensor that could withstand the tolerances for operations aboard the International Space Station as part of the Earth Systems Science Pathfinder (ESSP) project, ABYSS project planners satisfied the majority of mission requirements with the orbital track of the station while saving the costs of an independent satellite mission. But as was the case with CRYOSAT however, fate stepped in; the loss of the Space Shuttle *Columbia* in 2003 placed all ESSP projects for the International Space Station on hold. A re-scoping of the mission that involves flying an independent DDA sensor mission has been proposed (which includes the possibility to measure mesoscale variables now that the sensor is on a satellite that can be placed in a near-repeat orbit as opposed to the ISS which is not), but with a price tag of more than $100 million dollars ABYSS-Lite remains only a concept.[169]

Although altimetric datasets have proved extremely useful in many ways to the characterization of ocean variables both for scientific studies and for naval applications and scientists continue to propose new methods and missions such as CRYOSAT, WSOA and ABYSS, the future availability of satellite altimeter

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[168] David T. Sandwell, S.T. Gille, and W.H.F. Smith, *Bathymetry from Space: Oceanography, Geophysics, and Climate* (Bethesda: Geoscience Professional Services, 2002); David T. Sandwell, Walter H.F. Smith, Sarah Gille, Steven Jayne, Khalid Soofi, and Bernard Coakley, "Bathymetry from Space: White Paper in Support of a High-Resolution, Ocean Altimeter Mission," 2002 (accessed August 07, 2006); available from http://topex.ucsd.edu/marine_grav/white_paper.pdf.

[169] Mineart, *Emerging Space-Based Radar Altimeter Technologies;* R.K. Raney, D. L. Porter, J.R. Jensen, W.H.F. Smith, and D.T. Sandwell, "ABYSS: A Bathymetric Altimeter for the International Space Station," 2001 (accessed August 07, 2006); available from http://fermi.jhuapl.edu/abyss/documents/AIAA.pdf.

data is by no means secure. For the present, three satellites currently provide altimetry data of the resolution required to resolve mesoscale ocean variability now that TOPEX/POSEIDON and ERS-2 have ceased transmission of data: the U.S. Navy's GFO, NASA/CNES's JASON-1, and the European Space Agency's ENVISAT, all of which are destined to exceed design parameters for life-expectancy within a year of this writing.[170] Unless one or more of these systems exceeds life expectancy, some form of "altimetry gap" is expected in 2007 and at least until the projected launch and operational capability of NASA/CNES's JASON-2 OSTM in 2008 with a sensor life expectancy of four years.[171] Assuming JASON-2 reaches orbit successfully and becomes operational on time, data sparseness will remain a concern for resolving mesoscale features of interest with respect to ocean circulation which occur on scales that a single altimeter mission with JASON-2 specifications alone could not resolve.[172]

Beyond 2012 NASA and CNES have no follow on missions to JASON-2, the European Space Agency has no successor to ENVISAT, and the U.S. Navy has no GFO-FO; and it is entirely possible that the concern for a potential altimeter gap becomes instead alarm for an altogether loss of the dataset. With the time and investment required to develop satellite sensors and conduct mission planning, this lack of comparable follow-on systems (that would provide continuity of their datasets) for the impending loss of all three series of satellites that conduct mesoscale ocean studies is of particular note. Of possible alternatives in advanced stages of design that might be flown on the "short notice" of a few years - such as the three additional satellite altimeter missions mentioned in concept above - all would provide some additional data to complement JASON-2's traditional pulse limited altimeter for whatever timeframe it remained on orbit...but only the WSOA mission was truly designed to concentrate upon mesoscale ocean variability - and *that* mission utilizes the same JASON-2 satellite bus making altimetry subject to a single point failure.

The potential loss of satellite altimetry came about in a roundabout fashion through a series of unrelated incidents and decisions that together make the loss of the dataset a distinct possibility. Hopes to leverage

[170] Cotton and Menard, "The Future Role of Satellite Altimetry - Early Recommendations from the GAMBLE Project," (accessed).
[171] Committee on Earth Observation Satellites, "Earth Observation Handbook," (accessed).
[172] Cotton and Menard, "The Future Role of Satellite Altimetry - Early Recommendations from the GAMBLE Project," (accessed); L.L. Fu, *Wide Swath Altimetric Measurement of Ocean Surface Topography* (Pasadena: Jet Propulsion Laboratory, 2003).

the JASON-2 OSTM mission with the addition of the WSOA configuration faded only relatively recently, and with them the capability to obtain the equivalent of "four or five" high quality conventional altimeter mission datasets that would have been guaranteed for another four years. The rather spectacular losses of CRYOSAT and the delivery platform (when the entire shuttle fleet was grounded) for ABYSS – while unexpected and lamentable on many accounts – do not impact mesoscale ocean studies as directly even though both would have placed DDA technology on orbit; in fact if it were funded because of its placement on a free-flying satellite rather than the ISS, the revamped ABYSS-Lite mission description offers better prospects that the original ABYSS proposal for observing mesoscale variables on the requisite time and space scales to be of application. Even the coincidence of the WSOA decision in the same month as the launch failure of the CRYOSAT – not "tuned" for broad mesoscale study but which would provide crossover data that would prove useful as well as research into complementary climate considerations with respect to marine and terrestrial ice cover – did not make it patently apparent that continuity of satellite altimetric datasets of all forms was in peril. For until only a few months ago as of this writing, hopes remained alive that another altimeter mission would reach orbit…

As recently as early 2006 scientists had anticipated that even if data from the JASON, GFO and ENVISAT missions were no longer available to completely bridge the "altimetry gap" to the JASON-2 OSTM mission in 2008 (or provide for multiple sensors to be on orbit while JASON-2 was operational), nevertheless near-continuity of altimeter datasets would extend around another ten to fifteen years because of plans for future altimetry missions still on the drawing board that would reach orbit near JASON-2's end-of-mission. While not intended to be a successor to GFO in the way that ENVISAT followed ERS or JASON continued gathering data similar to TOPEX/POSEIDON, the United States planned to include an altimeter onboard one and possibly two missions of its proposed National Polar-orbiting Operational Environmental Satellite System series of low-earth orbiting environmental satellites. Scientists likely had little inkling that *these* plans became disrupted effectively more than a decade earlier, when a decision that was made at the end of the Cold War would set in motion a bureaucratic process that would ripple forward in ways that were not anticipated at the time. With the long lead times for satellite mission and sensor development, a future potential loss becomes oxymoronically apparent in hindsight, but the situation has

come to pass not so much because of poor planning or understanding as much as the coalescence of a number of unexpected twists and as a result of bureaucratic and programmatic decisions and compromises that demonstrate once more the complicated interaction of security considerations with environmental concerns.

Bad Reviews for a Performance Review

Acting on the recommendations of the 1993 National Performance Review led by his Vice President Al Gore, in May 1994 President Bill Clinton issued Presidential Decision Directive/National Science and Technology 2 (PPD/NSTC-2) regarding the convergence of U.S. polar orbiting operational environmental satellite systems. For three decades prior parallel programs in the Department of Commerce and the Department of Defense managed independent satellite programs to collect, process and disseminate meteorological, oceanographic, and space environmental data required by civilian and military users. The National Oceanic and Atmospheric Administration (NOAA) managed the Polar-Orbiting Operational Environmental Satellite (POES) program which focused on the "…collection of atmospheric data for weather forecasting, global climate change research and emergency search and rescue purposes." The United States Air Force oversaw operations of the Defense Meteorological Satellite Program (DMSP) that aimed to "…collect and distribute global visible and infrared cloud data and other specialized meteorological, oceanographic and solar geophysical data to provide a survivable capability in support of military operations." As part of its Mission To Planet Earth (MTPE) initiative, the National Aeronautic and Space Administration (NASA) developed a separate series of Earth Observing System (EOS) satellites to investigate climate change, and in addition NASA was considered to be the leading edge of research and development of new remote sensing and spacecraft technologies that contributed to both environmental research and satellite operations. Consequently, "The National Performance Review…called for converging the two operational satellite programs as well as incorporating appropriate aspects of NASA's EOS in order to reduce duplication of effort and generate cost-savings."[173]

[173] Office of the Press Secretary The White House, "Fact Sheet: U.S. Polar-Orbiting Operational Environmental Satellite Systems," May 10, 1994 (accessed August 09, 2006); available from http://clinton4.nara.gov/WH/EOP/OSTP/html/pdd2.html.

PDD/NSTC-2 directed the Department of Commerce and the Department of Defense to "…integrate their programs into a single, converged, national polar-orbiting operational environmental satellite system," which would operate according to four principles: "operational environmental data from polar-orbiting satellites are important to the achievement of U.S. economic, national security, scientific, and foreign policy goals; assured access to operational environmental data will be provided to meet civil and national security requirements and international obligations; the United States will ensure its ability to selectively deny critical environmental data to an adversary during crisis or war yet ensure the use of such data by U.S. and Allied Military forces [and] such data will be made available to other users when it no longer has military utility; the implementing actions will be accommodated within the overall resource and policy guidance of the President."[174] The Departments of Commerce and Defense and NASA were directed to create an Integrated Program Office (IPO) under a System Program Director who would report to a tri-agency Executive Committee (EXCOM) and be responsible for "…management, acquisition, and operation of the converged system." The EXCOM would"…coordinate program plans, budgets, and policies and…ensure agency funding commitments are equitable and sustained." The EXCOM was further charged with ensuring that "…both civil and national security requirements are satisfied." NOAA was made lead agency to support the IPO, and for "…interfacing with national and international civil user communities, consistent with national security and foreign policy requirements." The Department of Defense was appointed lead agency for major systems acquisition and NASA was made the lead for developing "…cost-effective technologies to meet operational requirements."[175]

The decision to converge U.S. military and civilian environmental remote sensing satellite programs sought to avoid duplication of efforts and save money, but it also made the requirements which underpinned the programs subject to competing policy and budgetary priorities of separate agencies. It was likely *not* a collaboration that would have been implemented during the Cold War. The Accompanying Report of the National Performance Review makes this evident: "Over the past 20 years, the POES and

[174] "Presidential Decision Directive/NSTC-2: Convergence of U.S. Polar-Orbiting Operational Satellite Systems," 1994 (accessed August 09, 2006); available from http://www.ipo.noaa.gov/About/NSTC-2.html.
[175] The White House, "Fact Sheet: U.S. Polar-Orbiting Operational Environmental Satellite Systems," (accessed).

DMSP programs have made numerous attempts to converge to the greatest extent possible. The programs have similar spacecraft, use a common launch vehicle, share products derived from the data, provide complementary environmental data to the nation, and work closely together on research and development efforts. In all, the programs achieve substantial commonality, but *national security concerns have precluded full convergence*. DOD has stated it would manage a converged system, but a single program run by DOD was and still is unacceptable given international concern over the militarization of space. Today, however, *with the end of the Cold War*, the issues which have precluded complete convergence seem to have diminished in importance. [emphases added]"[176] The NPR estimated that the NOAA, DOD, and NASA environmental satellite programs would have significant duplication of effort while costing taxpayers more than six billion dollars over the following ten years in research and development, production and operational costs, and cited speeches by various members of Congress who called for converging the systems to garner savings. The NPR estimated that $1.3 billion dollars could be saved by combining the programs. The NPR Accompanying Report further stated that synergies could be gained by converging programs - facilitating goals that could not be met by any of them separately including collecting certain "oceanographic and tropospheric wind data." By utilizing NASA's more advance spacecraft and instrument designs rather than designing independent satellite buses and sensors, further synergies could be achieved.[177]

The NPR acknowledged the problems posed by certain historical security concerns, including "…data deniability, orbit selection, international cooperation, and adequate oversight to ensure DOD concerns are adequately met." These concerns would be addressed by including capabilities to deny access using technologies "…such as that to deny cable-TV pay channels to non-subscribers" and by "…allowing DOD to influence orbits selection." If the Department of Defense proved reluctant to rely on foreign satellites to provide data upon failure of a U.S. satellite mission, its "…concern could be alleviated by maintaining one or more ground spare U.S. satellites at all times that could be launched if a foreign-controlled satellite ever became unreliable." To address oversight concerns on the part of Defense, various proposals were

[176] National Performance Review, "DOC12: Establish a Single Civilian Operational Environmental Polar Satellite Program," *Accompanying Report of the National Performance Review*, 1993 (accessed August 09, 2006); available from http://www.fas.org/spp/,ilitary/program/met/npr93_npoess.htm.
[177] Ibid. (accessed).

proffered that involved "…including DOD user and acquisition experts in the NOAA program offices and operations facilities, allowing DOD to fund and manage DOD-unique parts of the program, and establishing an interagency oversight group to which the program would have to report periodically to ensure that all agency requirements were adequately met." While NOAA, DOD, and NASA were described as "partners" in the efforts to converge polar orbiting environmental satellites under the National Performance Review, it is evident from the tone of the report that DOD was not considered a helpful playmate in the sandbox. Despite any Department of Defense misgivings, the merger was decreed by President Clinton in PDD/NSTC-2. With the end of the Cold War and a change of Administrations, security concerns were no longer being allowed to drive national policy. The closing statement of the National Performance Review Accompanying Report manages to somehow simultaneously identify and underestimate the obstacles, and highlights the schism between military and civilian relations and understanding: "The greatest difficulty in the proposal will be to ensure that a single national program under civilian leadership will be responsive to national security needs. However, these concerns can be met much more easily now than they could have in the past."[178]

To satisfy the observational requirements of the separate but complementary environmental remote sensing programs operated by NOAA and DMSP, an ambitious series of satellites was designed and designated the National Polar Orbiting Environmental Satellite System (NPOESS). The Integrated Program Office set about meeting the various requirements of the users by identifying a series of environmental parameters called Environmental Data Records that served the data needs of various sensing and measurement strategies. Since some sensor instruments can observe more than one parameter, the goal was to first identify a comprehensive set of observable geophysical variables and then determine the suite of sensors that could maximize collection within the constraints of an integrated system. NPOESS sought to replace four satellites on orbit – two DMSP and two POES satellites – with three polar orbiters flying in sun-synchronous low-Earth orbits (equator crossings occur at the same time above the same terrestrial reference point each day); since collection requirements differed with parameters, not all sensor suites would have to fly on each of the satellites, as long as temporal and spatial specifications could be met. The

[178] Ibid. (accessed).

IPO agreed upon the parameters to be collected in an Integrated Operational Requirements Document (IORD), the latest version of which was published in December 2001 as IORD II and which identified 56 EDRs that were divided into categories: Key, Atmospheric, Cloud, Earth Radiation Budget, Land, Ocean/Water, and Space.[179]

Six environmental data records were made Key Performance Parameters: atmospheric vertical moisture profile, atmospheric vertical temperature profile, global sea surface wind speed and direction, imagery, sea surface temperature, and soil moisture; these were parameters considered “so significant that failure to meet the threshold is cause for the system to be revaluated or the program to be reassessed and terminated.” Together the 56 EDRs would satisfy user requirements for aviation forecasting, medium range atmospheric forecasting (out to fifteen days), tropical cyclone forecasting, severe storm and flood warnings, forecasting ice conditions, solar and space environmental forecasts, hydrologic forecasts, forecast of the ocean surface and internal structure, seasonal and interannual climate forecasts, decadal-scale monitoring of climate variability, assessment of long-term global environmental change, environmental air quality monitoring and emergency response, tactical decision aids, and weapons systems utilization. Thirteen sensor and subsystem packages were designed to collect the 56 NPOESS EDRs, support data collection and instrument survivability, and continue a legacy of earlier POES satellites by carrying a search and rescue system that would receive and forward distress signals from beacons on Earth. Some of these sensors and systems were flying on satellites already on orbit, some were based upon other legacy sensors, and some were altogether new designs that brought with their improved capabilities some degree of programmatic risk inherent in the research, design, testing and operational deployment of new systems.[180]

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[179] James Choe, Hyung Jin Rim, and Bob E. Schutz, "NPOESS Precision Orbit Determination (POD) Using GPS and Satellite Laser Ranging (SLR) Data," July 19, 2005 (accessed August 16, 2006); available from http://eic.ipo.noaa.gov/IPOarchive/MAN/25AASAIAAextendedabstract-longversion.pdf; Joint Requirements Oversight Council, *National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Operational Requirements Document - II* (Washington, D.C.: Department of Defense, 2002); David A. Powner, *Polar-Orbiting Operational Environmental Satellites: Cost Increases Trigger Review and Place Program's Direction on Hold* (Washington, D.C.: United States Government Accountability Office, 2006).

[180] Choe, Rim, and Schutz, "NPOESS Precision Orbit Determination (POD) Using GPS and Satellite Laser Ranging (SLR) Data," (accessed); Powner, *Polar-Orbiting Operational Environmental Satellites: Cost Increases Trigger Review and Place Program's Direction on Hold*.

In various configurations on three satellites, NPOESS was designed to carry the Advanced Technology Microwave Sounder (ATMS) to measure microwave energy in the atmosphere and combine that data with infrared sounder data to create atmospheric temperature, humidity, and pressure profiles; the Aerosol Polarimetry Sensor (APS) to measure clouds and aerosols such as sea spray, smog and smoke; the Conical-scanned Microwave Imager/Sounder (CMIS) that will measure rain rate and water in clouds, soil moisture, atmospheric temperature and humidity, and ocean surface wind speed and direction; the Cross-track Infrared Sounder (CrIS) that will measure vertical distributions of temperature moisture, and pressure in the atmosphere; the Advanced Data Collection System (ADCS) which gathers information from environmental systems and redistributes it to other users via microwave relay; the Earth Radiation Budget Sensor (ERBS) that measures short- and long-wave radiation emitted by the Earth for use in climate studies; the Ozone Mapping and Profiler Suite (OMPS) that measures the amount and distribution of ozone in the atmosphere; a radar altimeter (ALT) to measure sea surface topography and ocean surface roughness to determine sea surface height, significant wave height and ocean surface wind speed for ocean forecasting and climate prediction models; the Search and Rescue Satellite Aided Tracking System (SARSAT) which detects and locates emergency positioning beacon signals for relay to rescue assets; the Space and Environmental Sensor Suite (SESS) to collect data to determine the effects of space weather on satellite systems; the Survivability Sensor (SS) which monitors for attacks on NPOESS instruments and the satellite bus; the Total Solar Irradiance Sensor (TSIS) which monitors solar activity; and the Visual/Infrared Imager Radiometer Suite (VIIRS) which collects imagery and radiometric data on the atmosphere, clouds oceans and land.

Between them, four of the NPOESS sensors – VIIRS, CMIS, CrIS, and ATMS – collect the data necessary to satisfy the six NPOESS Key Performance Parameters and are considered critical to the NPOESS constellation; all four are new sensors that will first fly on NPOESS or a planned NPOESS Preparatory Project (NPP) satellite intended to fly before NPOESS to provide experience with these sensors and their data streams before NPOESS becomes operational and responsible for collecting data records

currently gathered operationally by the POES and DMSP series satellites.[181] With success hinging on the seamless integration of many sensors – including new ones whose on-flight characteristics have yet to be operationally tested – a fair amount of risk was inherent in the NPOESS development from the start, but program managers remained confident, "It is the position of the DoD and the DOC that the NPOESS program does not have any major flaws in the design and ultimate delivery of capability to both military and civil users…[even while they]…acknowledge that there is an increased level of both technical and programmatic risk associated with the development and delivery of the NPOESS system."[182]

Significant among the thirteen NPOESS instruments and subsystems (for present considerations) is that the radar altimeter is the only sensor intended to collect exclusively ocean data at EDR technical specifications; other sensors which collect data for ocean EDRs concurrently gather EDR information in the atmosphere and over land…while only the altimeter was included solely to measure ocean variables at thresholds identified in IORD II.[183] Equally significant however, is that none of the three altimeter-specific EDRs – Ocean Wave Character, Sea Surface Height / Topography, and Surface Wind Stress – were made Key Performance Parameters, and one of them, Surface Wind Stress, could also be collected by CMIS.[184] Among 56 EDRs, three is rather a small number to fly a unique instrument that places design, fiscal and operational demands on the mission - especially when none of the environmental data records were designated through the IPO process to receive the status of a KPP. What is more, based upon the compromise design of a satellite intended to satisfy so many requirements and support so many sensor systems, the potential benefit of flying an altimeter aboard NPOESS has come into question from a scientific perspective. A dual frequency pulse limited satellite altimeter similar to that aboard JASON is proposed for inclusion on the third and possibly the sixth satellite of the series; already this limits results

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[181] Powner, *Polar-Orbiting Operational Environmental Satellites: Cost Increases Trigger Review and Place Program's Direction on Hold*.
[182] Office of Management and Budget, "National Security Space Programs Assessment," January 26, 2006 (accessed August 16, 2006); available from http://www.whitehouse.gov/omb/expectmore/detail.10003205.2005.html.
[183] Craig S. Nelson and John D. Cunningham, "The National Polar-Orbiting Operational Environmental Satellite System: Future U.S. Environmental Observing System," 2002 (accessed August 16, 2006); available from http://eic.ipo.noaa.gov//IPOarchive/SCI/sensors/AMS-2002_Paper_3.1_NPOESS-Nelson.pdf.
[184] Kevin Souza, Chad Fox, Kerry Grant, and Scott Turek, "NPOESS Interface Data Processing Segment (IDPS) Architecture and Software," (accessed August 18, 2006); available from http://eic.ipo.noaa.gov/IPOarchive/MAN/17attached5549-4SPIEManuscript.pdf.

that can be expected from an altimeter mission of this nature with respect to spatial and temporal coverage and the continuity of existing altimeter data records.[185]

The planned 2012 launch of the third NPOESS spacecraft carrying the first altimeter likely will not provide for adequate on orbit cross correlation with JASON-2 data before the expected loss of that mission, nor for multiple-sensor crossover comparisons unless JASON-2 lasts beyond design-life. The inclusion of an altimeter would be better than not having a sensor on orbit *at all*, but flying an altimeter on a low earth orbit (LEO) sun-synchronous satellite together with a host of other earth, atmosphere and ocean sensors presents its own suite of challenges: the proposed near-polar NPOESS orbit determines less orthogonal self-track crossovers, reducing their utility for orbital corrections and providing less three dimensional data for ocean topology; the orbital parameters of the NPOESS satellites compared to TOPEX/POSEIDON and JASON missions would force heavy reliance on suboptimal tide gauge data to make necessary corrections between their data to compare altimeter records - on a sun synchronous orbit, various tidal constituents (the S2 daily constituent, K1 and P1 annual constituents, and the K2 semiannual constituent) would be aliased into the NPOESS altimetry dataset; flying at a lower altitude orbit than TOPEX/POSEIDON and JASON missions means that different gravity variations would affect NPOESS while in addition the satellite bus and sensors would be exposed to higher atmospheric drag - which would then require more spacecraft orbital adjustments. Spacecraft corrective maneuvers preclude sensors from gathering data and alter the mass of the satellite due to fuel consumption…which subsequently affects POD calculations. Frequent and necessary altimeter calibrations requiring a series of spacecraft attitude adjustments on a platform with many other moving sensors would also prove problematic. One further but extremely significant consideration is that NPOESS will utilize only GPS data for orbital determination without DORIS or SLR backup, a strategy that already proved its limitations on GFO and would render altimetry from NPOESS useless in the event of a similar failure.[186] Including an altimeter on a platform such as NPOESS keeps a sensor on orbit, but represents a compromise which minimizes its utility.

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[185] Choe, Rim, and Schutz, "NPOESS Precision Orbit Determination (POD) Using GPS and Satellite Laser Ranging (SLR) Data," (accessed).
[186] Mineart, Rau, and Finkelstein, "An Examination of U.S. Plans for Meeting Operational Ocean Observation Needs with Radar Altimetry."

While the importance of satellite altimeters to many aspects of ocean investigations has been made apparent through earlier discussion, it must be remembered that their inception and – in at least one important instance - continued funding hinged on their utility for naval applications. By the time the GEOSAT satellite became inoperative at the end of 1989 it had achieved its initial geodetic mapping mission, but additionally demonstrated the importance of altimetry data for antisubmarine warfare and naval operations. When they became available a few years later, altimeters flying aboard the TOPEX/Poseidon and ERS-1 satellites provided this all-weather capability for deriving sea surface height, significant wave height, and wind speed for operational and modeling utilization by naval oceanographers – but they were not DoD missions and despite the fact that they generated comparable or better measurements, data availability (and deniability) could not be guaranteed. To maintain coverage after these sensors were expected to reach their life-expectancy and to exact some measure of control over data availability, a GEOSAT Follow-On (GFO) mission was funded and flown by the U.S. Navy. At the time that the satellite was designed and bids were let to industry in 1992, it was not clear that the former Soviet submarine threat would devolve as completely and as quickly as it eventually did, or whether new undersea warfare threats as a result of proliferation would quickly become established; but other Navy missions envisioned in the littoral would be dependent on ocean variability and the satellite's design parameters were specified with this in mind.[187]

At present the security situation is not so recently removed from the Cold War - where antisubmarine warfare was well understood and respected – and a satellite altimeter that represents possibly the only sensor that will exist on orbit providing measurements of sea surface height and topography is not considered a critical sensor providing even one of six Key Performance Parameters. From dedicated GEOSAT and GEOSAT Follow-On missions that were undertaken to place solely a satellite altimeter and instruments to support the accuracy of that sensor on orbit, satellite altimetry has been relegated to second tier on a platform whose orbital characteristics will likely further degrade the utility of the altimetric dataset. Newer technologies that support the more efficient gathering of altimetric data over wider areas and without requiring multiple satellites for adequate spatial coverage, and that have better fidelity in

[187] "Geosat Follow-On [GFO]," (accessed); McQueary, "R&D Required for Remote Sensing."

coastal regions over the type planned for NPOESS, have not made it onto missions intended to investigate mesoscale variability. Analysts note that altimetry suffers from competing demands within the post-Cold War Navy, “The limitations of pulse-limited altimeters in coastal regions, the difficulty of employing legacy sonar tactics and technologies in littoral regions, the absence of any credible open-ocean threats, and the challenge of quantifying the value of the Navy’s investment in emerging altimeter technologies have made it more difficult to justify S&T and RDT&E funding and have been accompanied by reductions in the level of corporate support for Navy’s science community investments in improved SSH data assimilation, ocean modeling capabilities, and new instrument technologies.”[188] This competition for resources is not strictly confined to altimetry, “Also, Department of Defense budget demands associated with the recent and ongoing military operations in southwestern Asia and elsewhere have led to necessary Navy reductions in S&T and RDT&E, including resources for earth science applications of all remotely sensed data.”[189]

The diminished level of attention for satellite altimetry in NPOESS development does not mean that the military requirements perspective of NPOESS programmatic responsibilities have received short-shrift. Some aspects of the DMSP capabilities have received specific attention of late, and planned improvements on NPOESS are anticipated, “DMSP is a critical element of the DoD’s force structure enabling current and predictive battlespace awareness in support of the full range of strategic, tactical, and special military and intelligence operations. DMSP’s vantage point in space allows it to “reach-into” data denied areas collecting weather observations required for effective mission planning and execution. This access has been particularly critical in supporting the Global War on Terror (GWOT), which is primarily being fought in remote areas that do not have indigenous environmental monitoring networks of sufficient density and fidelity to support US operations and weapons systems. NPOESS continues this mission by serving as a single, integrated polar-orbiting satellite system satisfying both civil and military national security requirements for space-based, remotely sensed environmental data that will significantly improve weather forecasting and climate prediction to enable effective employment of weapons systems and aid in the

[188] Mineart, Rau, and Finkelstein, "An Examination of U.S. Plans for Meeting Operational Ocean Observation Needs with Radar Altimetry."
[189] Ibid.

protection of national resources (life, safety, and property)."[190] Like it was for the Cold War in ocean areas, data scarcity in terrestrial areas where the Global War on Terror is being fought is considered of primary importance for environmental security considerations of US military forces; consequently priority is placed on sensors and mission design that incorporate these concerns. One area where this is evident is the collection of satellite imagery that provides the capability to detect dust storms using the Moderate Resolution Imaging Spectrometer (MODIS) sensor on the NASA EOS Aqua satellite; MODIS is the legacy system for VIIRS on NPOESS which will provide even finer detail.[191]

With the degree of effort currently being expended on supporting ongoing combat operations in Iraq and Afghanistan, and not so much activity going on in the maritime aspects of the Global War on Terror, little attention has been spent on the sensor so critical for undersea warfare applications should the need again arise. What becomes further evident is that other environment-security considerations such as those potentially posed by climate change are not being addressed. With so much of the security-inspired scenarios for abrupt climate change based upon changes in the thermohaline circulation of the ocean in small regions – mesoscale changes that would have sea surface topographic signatures – and involving the impact of such threats as sea level rise whose long-term signature has been recorded dramatically over the last decade by TOPEX, JASON and GFO, satellite altimetry might be thought to merit a higher position on the NPOESS hierarchy. Cognizance for climate change science nationally does not fall under DoD, but rather resides with NOAA; nevertheless as the chief partner agencies in defining NPOESS priorities, the relative importance of the issue and the uniqueness and criticality of the sea level and sea surface topography datasets to both NOAA's and DoD's areas of purview would seem to elevate the collection of satellite altimetry data because of overlapping NPOESS mission priorities. While it may be that the design and integration of many other climate related NPOESS sensors spreads the attention of NOAA personnel across many areas of climate research and not just the variables of oceanographic significance, the same cannot be said for military participants in this discussion who would likely be familiar with at least some of the potential for climate threats to security if not more traditional environmental impacts on military

[190] Office of Management and Budget, "National Security Space Programs Assessment," (accessed).
[191] Dave Jones, Craig S. Nelson, and Mike Bonadonna, "NPOESS...21st Century Space-Based Military Support," *Earth Observation Magazine* 13, no. 4 (2004).

operations. This failure to emphasize altimetry for its importance in detecting the onset of potentially wide-ranging environmental impacts on security, in addition to its relative importance for applications in support of undersea warfare, perhaps best demonstrates where these two security considerations reside with Defense planners for the time being.

The auspicious projections made by the National Performance Review and outlined in PDD/NSTC-2 for combining the POES and DMSP satellite programs appeared on track if not ahead of schedule early on. The IPO met and devised the IORD parameters which led to instrument selection and mission planning. Liaison was conducted with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) to develop complementary observing strategies between NPOESS and EUMETSAT's METOP series of polar-orbiting weather satellites. A significant milestone was achieved when Satellite Control Authority for DMSP satellites was transferred from the U.S. Air Force Space Command to NOAA's Satellite Operations Control Center in May 1998. By fiscal year 2001, it was estimated that $670 million dollars had been saved through program integration.[192] The synergies gained by leveraging complementary programs seemed to be progressing as designed. But these were organizational and programmatic processes that the NPOESS IPO had significant control over; at the same time, however, decisions made in the legacy DMSP program – still responsible for remaining satellites until placed on orbit – would affect NPOESS progress.

In 2002, launch delays of a DMSP satellite caused delays for a follow-on, and the Department of Defense subsequently reduced funding for NPOESS across four fiscal years by $65 million dollars. As NOAA was required to mirror DoD funding, it also cut support which instigated a major programmatic ripple throughout NPOESS, affecting procurement and launch schedules. When a new baseline was developed for the program in 2004, costs of the NPOESS program had grown by more than a billion dollars; from originally proposed costs of $6.5 billion – which had increased half a billion almost immediately after the program began to $7 billion – the program had already inflated more than projected

[192] NOAA Public Affairs Office, "The National Polar-orbiting Operational Environmental Satellite System (NPOESS)," August, 2002 (accessed June 27, 2006); available from http://www.publicaffairs.noaa.gov/grounders/npoess.html.

savings of the original NPR estimate. What is more, in areas of research, development and integration of the NPOESS sensor technologies that proceeded apace, program management and technical challenges became evident. Design challenges with key instruments including the VIIRS sensor were incurring overruns, and managerial problems with subcontractors exacerbated the situation. By November 2005 NPOESS officials estimated that costs had ballooned to $10 billion dollars and that the first and second satellites would not meet launch schedules by seventeen and six months respectively. What becomes significant – aside from taxpayer expense and program performance in general – is that delays widen the gap between the last POES launch and when NPOESS backup would be available in the event that the POES fails on launch or in orbit to at least three years. "During that time, critical weather and environmental observations would be unavailable – and military and civilian weather products and forecasts could be significantly degraded."[193] The bad news was not over.

The spiraling costs of the NPOESS program triggered a requirement for review that had been levied on Department of Defense acquisition programs that was known as a Nunn-McCurdy Review. If costs of a program increase by more than 25 percent, the Department of Defense was required to certify that program to Congress within a specified timeframe or no longer obligate funds for it. There were four formal aspects of this certification: that the program is essential to national security; that there is no alternative capable of providing equal or greater military capability at less cost; that new reasonable cost estimates have been developed; and that program management structure is adequate to manage and control costs.[194] In January 2006 the Secretary of the Air Force notified Congress that the NPOESS program had exceeded the Nunn-McCurdy threshold and that certification had begun together with the other members of the NPOESS IPO. Even though Nunn-McCurdy was only a DoD acquisition mandate, this was the first time that an interagency program had triggered such a review and the other program participants had been invited to take part in the review and certification of the program. Four teams were paneled to investigate each of the Nunn-McCurdy criteria and each included DOD, NOAA, and NASA participants. The Undersecretary of

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[193] Eli Kintisch, "Stormy Skies for Polar Satellite Program," *Science* 312, no. 5778 (2006); Powner, *Polar-Orbiting Operational Environmental Satellites: Cost Increases Trigger Review and Place Program's Direction on Hold*.

[194] Powner, *Polar-Orbiting Operational Environmental Satellites: Cost Increases Trigger Review and Place Program's Direction on Hold*.

Defense for Acquisition, Technology, and Logistics delivered the results of the Nunn-McCurdy Review to Congress on June 5, 2006.

NPOESS was certified, but with a number of major changes: total program acquisition and launch costs were estimated at $11.5 billion; NPOESS would fly only four satellites instead of six and rely on a EUMETSAT METOP satellite to provide the third daily orbit in conjunction with two NPOESS satellites (early concerns with obtaining requisite data from foreign satellites were not addressed); the first NPOESS launch slipped from 2008 (as initially proposed) until 2013 and the NPOES Preparatory Project (NPP) will not fly until 2009 instead of 2006; a number of sensors will be dropped from NPOESS including one critical sensor designed to collect data important to all six Key Performance Parameters (although satellite design will accommodate the sensors if money is later added to the program); the CMIS sensor will be dropped from the program and a sensor with some of its capabilities will be substituted, although not by the first NPOESS launch which means that some data collection – including ocean wind speeds – will have to rely on the METOP satellite; a series of management reforms including some related to the EXCOM will be implemented; and changes must be renegotiated with the primary contractor, resulting in potential further delays and costs that might increase above the projected $11.5 billion dollar figure.[195] With some 70 percent cost growth and slippage of the program by enough years to place the entire national remote sensing strategy into peril, the NPOESS program did not turn out to be the model that the National Program Review had projected a little over a decade earlier.

When the dust settled form the Nunn-McCurdy Review, NPOESS was only a shell of its former design. Its sensor suite was decimated. A scaled down version of the Conical Scanning Microwave Imager / Sounder (CMIS) remains to be developed, and one of two planned Ozone Mapping and Profiler Suites (OMPS) survived the re-scoping certification process, but six other sensors or instrument packages were removed altogether: the Aerosol Polarimetry Sensor (APS), the Total Solar Irradiance Sensor (TSIS), the Earth radiation Budget Suite (ERBS), the Survivability Sensor (SS), the Space Environment Sensor Suite

[195] U.S. House of Representatives Committee on Science, "The Future of NPOESS: Results of the Nunn-McCurdy Review of NOAA's Weather Satellite Program," in *Committee on Science* (Washington: U.S. House of Representatives, 2006).

(SESS), and the Radar Altimeter (ALT). The surviving instruments consisted of three environmental sensors: the Visible Infrared Imager Radiometer Suite (VIIRS), the Cross-track Infrared Sounder (CriS), and the Advanced Technology Microwave Sounder (ATMS), together with whatever remains of a redesigned CMIS; and still onboard were two instrument suites: the Advanced Data Collection System (ADCS) and the Search and Rescue Satellite-Aided Tracking System (SARSAT).[196] The approach to the certification process emphasized operational weather sensing capabilities because of the potential for other satellite failures in the near-term.[197] As a result, NPOESS was pared down to an operational weather satellite that retained the data forwarding and search and rescue capabilities of the present polar orbiters, while its utility for tackling longer term climate studies was significantly diminished from its planned inception.

This sort of reduction in capability had been feared by scientists concerned with climate monitoring, "The study of climate processes requires a coherent, comprehensive system that carefully balances research requirements that are sometimes in conflict with operational requirements. Long-term, consistent data sets require careful calibration, reprocessing, and analysis that may not be necessary to meet the needs of short-term forecasting. Acquisition of multiple copies of a satellite sensor may be the simplest and most cost-effective means to ensure data continuity, but this strategy may preclude the insertion of new techniques to improve the observations in response to lessons learned during analysis of long data records. Such conflicts are difficult to resolve and are complicated by differences in agency cultures, charters, and financial resources." Other conflicts between research and operational strategies were noted, "Sensors developed for NASA ESE [Earth Science Enterprise] research missions are generally intended to make ambitious state-of-the-art measurements. They are typically relatively complex and often are developed in small numbers, or even one of a kind. In contrast, sensors for operational weather forecasting missions are generally less expensive to build and operate and are designed with reliability as a key requirement.… Developing instruments appropriate for both research- and operational-type missions that can be sustained over the longer periods characteristic of a climate research program will be a particular challenge as EOS

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[196] Jeffrey Mervis, "Climate Sensors Dropped From U.S. Weather Satellite Package," *Science* 312, no. 5780 (2006); Jeremy Singer and Brian Berger, "NPOESS Loses Research Luster," June 19, 2006 (accessed June 30, 2006); available from http://www.space.com/spacenews/archive06/Npoess_061906.html.
[197] Kintisch, "Stormy Skies for Polar Satellite Program."

and NPOESS satellites are integrated."[198] NPOESS had sought programmatic paydirt: cost savings while expanding capability. Instead the United States is faced with increased costs and dramatically increased risk with its future environmental remote sensing strategies in support of both military and civil operations.

The Department of Defense position on the post-Nunn-McCurdy NPOESS was delivered by the Undersecretary of the Air Force at the Congressional Hearing over the results of the certification process. Undersecretary Ronald Sega informed the House of Representatives Science Committee that he was, "confident with the support and guidance of this committee, the NPOESS program will enhance the space-based weather sensing capabilities needed to meet our national security requirements in the coming years."[199] From a perspective emphasizing weather prediction, this may well prove accurate; but from other environmental considerations including remote sensing of the oceans both for antisubmarine warfare purposes as well as climate change research (from a security perspective or otherwise), this statement is not as inclusive. After the June 6, 2006 hearing on the Nunn-McCurdy review it was reported that the U.S. Navy was already investigating "how to replace an altimeter that would have monitored seas surface height and wave characteristics."[200] At the same time, the head of NASA's Earth Observing System downplayed the loss of the altimeter, inferring that it would not be a blow to climate researchers since a data record of global sea level was already in place back through 1991depicting this parameter's variability and rise, and that in addition the value of data from an NPOESS altimeter would have proved of little utility because of the orbital parameters of the satellite.[201]

While the EOS director's comments about the NPOESS dataset might have had validity based on earlier discussions within this chapter, it is difficult to accept that he would view the collection of one decade of data conclusive to a parameter as important as sea level rise for climate change monitoring and research…and was not attempting to place the proper "spin" on a difficult problem. Viewpoints of changes

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198 Space Studies Board Committee on Earth Studies, *Issues in the Integration of Research and Operational Satellite Systems for Climate Research: Part I. Science and Design* (Washington, D.C.: National Academy of Sciences, 2000).
199 U.S. House of Representatives Committee on Science, "The Future of NPOESS: Results of the Nunn-McCurdy Review of NOAA's Weather Satellite Program."
200 Mervis, "Climate Sensors Dropped From U.S. Weather Satellite Package."
201 Singer and Berger, "NPOESS Loses Research Luster," (accessed).

to the program in the wake of the Nunn-McCurdy certification of NPOESS span a spectrum from utter frustration to acceptance of difficult programmatic decisions in times of budgetary limitations. "Essentially, NPOESS is saying NOAA won't be doing climate. Basically, no one is going to do climate," according to a researcher at the University of Washington's Applied Physics Laboratory.[202] The head of the National Academy of Science's Earth Science Decadal Survey research program, Dr. Richard Anthes, was sobered, "It's going to be hard to even hold our own in terms of capabilities to do weather forecasting and monitoring and observing the climate. It's really a severe blow to the plans... This is not just a small degradation. It's a huge loss of the expected capability combined with a delay of what's left. It makes you wonder if it's even worth going forward with NPOESS in its reduced form."[203] In the end, it appears that a large number of bureaucratic factors was involved in the implosion of NPOESS as an earth observation platform instead of a weather satellite, but that does not mean some interested parties won't place the blame on others; after being promised a system that would avoid unnecessary duplication while providing enhanced remote sensing capabilities, "…climate researchers are worried that they could be left with 20th century tools if military officials decide that the continuing costs of the wars in Iraq and Afghanistan force them to build a less-capable NPOESS."[204]

The potential loss of satellite altimetry is inspiring something of a reassessment of what this data set means to the military and civil oceanography communities. Satellite altimetry has become a critical tool for the study of the oceans in the thirty or so years that data have been available, but just as it has become evident that its future may no longer be safe in the pantheon of airborne ocean sensors, its success when first flown as a sensor for oceanic variables was not at all a foregone conclusion and early support among civilian research institutions was lackluster.[205] Launched initially to provide important data in support of Cold War submarine operations, satellite altimeters revealed entirely new information about mesoscale ocean variability that subsequently was exploited via models that informed acoustic tactical decision aids; but naval oceanographers were not the only beneficiaries. Because of its spatial and temporal resolution as

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[202] Quoted in Mervis, "Climate Sensors Dropped From U.S. Weather Satellite Package."
[203] Quoted in Singer and Berger, "NPOESS Loses Research Luster," (accessed).
[204] Kintisch, "Stormy Skies for Polar Satellite Program."
[205] Carl Wunsch, "Altimetry Since 1980: Past, Present, Future," in *15 Years of Progress in Radar Altimetry* (Venice: European Space Agency, 2006).

well as the precision of its data, satellite altimetry also opened new windows for ocean scientists that would change forever the scientific view of the oceans.

At a conference reflecting on the importance of the spaceborne altimeter to oceanographic research, Dr. Carl Wunsch described this revelation, “The greatest achievement of the altimeter is that it has showed us that the ocean system changes rather dramatically everyday and has shifted the view of it from this almost geological phenomenon creeping along very slowly to something much more interesting in which fluid is moving in all directions at all times.”[206] Another researcher described altimetry as the “three-pointed trident of the god of the sea, Neptune” for its tripartite contributions to science: altimetry contributed to geophysics through the maps that were constructed of the marine geoid and the ocean floor; it served oceanographers by the observations it made available of surface geostrophic currents, tides, planetary waves, and sea-level change; and it improved geodesy by means of improved frames of terrestrial reference.[207] The significance of satellite altimetry to the study of ocean climate processes was also evident, “Before the advent of radar altimeters our understanding of the world’s [ocean] climate was based on a few instruments moored off the coasts of Europe, Japan and North America and visual observations taken from merchant ships. This information was patchy and in many cases of poor quality. It was difficult to relate what was happening at one location with another…[until] a series of satellite instruments…made consistent measurements…across the globe…[and] with longer records came the ability to look at inter-annual variability.”[208]

Altimetric measurements were critical to ocean studies related to sea level aspects of ongoing climate change research, providing the data set for the most significant revelations about recent changes, “Satellite altimeter observations show that global mean sea level has been rising over the past decade at a rate of about 3 mm/yr, well above the centennial rate of 1.8 mm/yr. This has been occurring despite the presence

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[206] "Radar Altimetry Revolutionises the Study of the Ocean," 2006 (accessed June 26, 2006); available from http://pda.physorg.com/lofi-news-ocean-radar-waves_11794.html.
[207] Michael Lefebvre and Robert Stewart, "History of Altimetry, 1960-1992," in *15 Years of Progress in Radar Altimetry* (Venice: European Space Agency, 2006).
[208] Peter Challenor, David Woolf, Christine Gommenginger, Meric Srokosz, David Cotton, David Carter, and Nathan Sykes, "Satellite Altimetry: A Revolution in Understanding the Wave Climate," in *15 Years of Progress in Satellite Altimetry* (Venice: European Space Agency, 2006).

of large geographical variations, including broad areas of falling sea level."[209] Determining contributions to sea level rise from thermal expansion of sea water (steric effects) and from freshwater additions (eustatic effects) has been a central concern of climate researchers; altimetric capabilities to measure changes in the height of polar ice fields and the spatial extent of sea ice have been able to discern that close to twenty percent of this sea level rise is likely eustatic due to continental ice melt.[210] Planetary internal ocean waves on the order of 500 to 1000 kilometers also became observable for the first time as a result of satellite altimetry; long theorized to have existed, they were impossible to measure because of their small surface signature (on the order of only ten centimeters across these enormous wavelengths) until broad satellite-based measurements became possible. These waves are significant as it is thought that they may be responsible for the main circulation patterns of the oceans and are a potential mechanism for upwelling nutrients from the deep sea as a critical element of the global carbon cycle.[211]

Altimetry has opened many new lines of investigation in the oceans, yet despite their many military and civilian applications satellite altimeters may disappear in a matter of a few years after JASON-2 completes its mission – assuming it reaches orbit and becomes operational. Ironically JASON-2's design end-of-life is in the year 2012, just around the period that Kyoto Protocol goals are to be met; if there were ever a critical time to measure climate change processes, it would appear to be then after such a worldwide effort to alter practices to address the phenomenon. But until some issue with enough resonance in military or civilian decision-making circles arises to alter current decisions, instead of being compared to Neptune's Trident because of its utility for ocean remote sensing satellite altimetry may instead be better characterized as a fork - as in the expression "stick a fork in it...because it's dead."

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[209] Laury Miller and Bruce C. Douglas, "Comparing Global Sea Level Rise Estimates from Satellite Altimetry and a Global Ocean Reanalysis: 1993-2001," in *15 Years of Progress in Radar Altimetry* (Venice: European Space Agency, 2006).
[210] James A. Carton, Seymon A. Grodsky, and Benjamin S. Giese, "Application of Ocean Reanalysis to the Problem of Global Sea Level Rise," in *15 Years of Progress in Radar Altimetry* (Venice: European Space Agency, 2006); "Radar Altimetry Shows Warming Affecting Polar Glaciers," 2006 (accessed June 28, 2006); available from http://www.spacemart.com/reports/Radar_AltimetryShows_Warming_Affecting_Polar_Glaciers.html.
[211] "Radar Altimetry Revolutionises the Study of the Ocean," (accessed).

Hell Hath No Fury…Like a Category Five

Even after the very active Atlantic tropical cyclone season in 2004, few people were prepared for the unrelenting wave of storm activity in 2005. Early predictions were for an above average season, with an expected eleven named tropical storms of which six were expected to intensify into hurricanes; nobody foresaw a season with more than twice that number, and that the twenty-eight named storms that formed would break the record set over seventy years earlier making 2005 the most active season in a 150-year database reaching back to 1851.[212] It became necessary to invoke a naming convention that applied letters of the Greek alphabet to storms once the approved list of twenty one names had been exhausted for the first time in its history of use by the National Hurricane Center. Fifteen of these named storms reached hurricane strength; of these three grew to most powerful Category Five level on the Saffir-Simpson Hurricane Scale (Katrina, Wilma, and Rita) and one of these, Wilma, recorded the lowest central pressure ever reported from an Atlantic storm of 882 millibars.[213] Claiming well over one thousand lives and inflicting somewhere above $75 billion dollars in damages, Hurricane Katrina reset the destructive benchmark for future reference and shocked the United States and the world with the damages and large loss of life it inflicted to the Gulf Coast.[214]

The fact that Katrina caught the American populace so unprepared inspired an immediate round of finger pointing among government officials, and over and over again television news reporters asked how the citizens of South Mississippi and Louisiana could be surprised to the degree that they were by the onset of the storm and the danger that it posed. Although by the standard measure not nearly the most powerful storm to come ashore along this coastline – Hurricane Camille packed considerably higher winds than the Saffir-Simpson Category Three strength winds that Katrina possessed when she went “feet dry” in

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[212] Jack Beven, "A Record Smasher: Overview of the 2005 Atlantic Hurricane Season," in *60th Interdepartmental Hurricane Conference* (Mobile: Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2006); William M. Gray and Philip J. Klotzbach, "Summary of 2005 Atlantic Tropical Cyclone Activity and Verification of Author's Seasonal and Monthly Forecasts," 2005 (accessed February 7, 2006); available from http://hurricane.atmos.colostate.eud/forecasts/2005/nov2005/.
[213] Lynn K. Shay, Benjamin Jaimes, Eric Uhlhorn, Jodi Brewster, Michelle Mainelli, John Lillibridge, and Peter Black, "Hurricane Trifecta: Katrina, Rita and Wilma Interactions with the Loop Current," in *60th Interdepartmental Hurricane Conference* (Mobile: Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2006).
[214] Beven, "A Record Smasher: Overview of the 2005 Atlantic Hurricane Season."

Louisiana and Mississippi – it had been so many years since such a display of natural power, that Katrina's ferocity also raised questions as to whether hurricanes were somehow different than they had been. A decade earlier the claim might have been "El Nino!" when that phenomenon appeared everywhere as the answer to some climatic anomaly; but after growing public awareness over years of international negotiations on the subject, the question that now was asked was whether global warming was the root cause. An article published in *Nature* earlier in the same month that Katrina devastated the Gulf Coast quickly resonated with a larger audience eager to learn whether more of the same was in store. Dr Kerry Emanuel's conclusion after studying trends of storm frequency and intensity over the previous thirty years did little to allay fears; his research demonstrated that hurricane potential in terms of net power had increased and correlated with rising tropical sea surface temperature in the Atlantic…and global warming. "My results indicate that future warming may lead to an upward trend in tropical cyclone destructive potential, and – taking into account an increasing coastal population – a substantial increase in hurricane-related losses in the twenty-first century."[215]

In the aftermath of a storm as destructive as Katrina, it did not take much for an empirical link between hurricane frequency and intensity with global warming to quickly cross from the scientific to the political realm.[216] Barely a week had passed before Germany's environment minister ascribed the severity of Katrina at least in part to the effects of global warming, and accused President Bush of ignoring economic and human costs of this phenomenon through his position on the Kyoto protocol.[217] Not everyone agreed with this theory however. Testifying before Congress, National Hurricane Center Director Max Mayfield and National Weather Service Director David Johnson said that the increase in the frequency of hurricanes over the previous ten years was part of a natural multidecadal cycle that had another ten to twenty years to run before reverting to a less active period. They warned, however, that the danger was greater than the

[215] Kerry Emanuel, "Increasing Destructiveness of Tropical Cyclones Over the Past 30 Years," *Nature* 436 (2005).
[216] "The Gathering Storm," *Nature* 441, no. 7093 (2006).
[217] Thomas Hayden and Megan Barnett, "Bigger, Badder Blows," *U.S. News and World Report*, September 12, 2005, 39.

previous cycle of higher activity that took place between 1920 and 1966 because of the greater number of people that lived along the coast in hurricane-prone areas.[218]

Many other scientists agreed that the apparent trend in hurricane frequency was a natural one, and that globally hurricane activity averaged out about the same; observed increases in Atlantic activity were matched by decreases in Pacific and Indian Ocean storms, with any given year averaging ninety tropical cyclones worldwide.[219] While agreeing that globally averaged tropical cyclone activity remained consistent, Emanuel disagreed that the cycle was purely one of natural variability. Following up on his research reported just before Katrina, together with another researcher he undertook a study that sought to identify anthropogenic forcing as a result of climate change separate from the multidecadal pattern other scientists claimed to be at the root of Atlantic tropical cyclone variability. Their results indicated that in this ocean basin "anthropogenic factors are likely responsible for long-term trends in tropical warmth and tropical cyclone activity." Additionally, if it were not for some upper atmospheric cooling – also caused by anthropogenic influence by means of aerosols – the authors concluded that tropical cyclone activity would have been even higher.[220]

All of this does not mean that Hurricane Katrina was *caused* by global warming, and Emanuel labeled such a claim to be "absurd."[221] In any regard, Emanuel's provocative assertion that increased tropical cyclone activity was attributable to global warming drew a fair share of academic fire, but also instigated a flurry of new research into an area about which there is still much that is not known: hurricane cyclogenesis.[222] If sea surface temperatures were rising, as reported not only by researchers like Emanuel but by such bodies as the IPCC after reviewing relevant research in the field, a link between sea surface temperatures and storms was a natural correlation to expect given their importance to storm dynamics.

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218 "Weather Officials Warn of Future Increases in Hurricane Activity," *Sea Technology* 46, no. 11 (2005): 9.
219 Hayden and Barnett, "Bigger, Badder Blows."
220 M. E. Mann and Kerry Emanuel, "Atlantic Hurricane Trends Linked to Climate Change," *EOS* 87, no. 24 (2006).
221 Kerry Emanuel, "Anthropogenic Effects on Tropical Cyclone Activity," 2006 (accessed July 11, 2006); available from http://wind.mit.edu/~emanuel/anthro2.html.
222 Environment News Service, "Global Warming Kicked 2005 Hurricanes Up A Notch," June 26, 2006 (accessed June 26, 2006); available from http://www.ens-newswire.com/ens/jun2006/2006-06-26-01.asp.

Hurricanes are ocean storms, fueled by the thermal energy of ocean waters through a complex air-sea interaction in which convective atmospheric cells become closed circulations that pump themselves up through the addition of heat when water evaporates at the sea surface – a process that increases with sea surface temperature. Atmospheric steering currents and the influence of vertical wind shear play integral parts in the development – or death – of nascent cyclones. Identifying one element of cyclogenesis and holding it apart from all of the other essential pieces does not a storm form. But as a fundamental element of tropical cyclone formation, elevated sea surface temperature is a necessary precondition and Emanuel's theory that higher sea surface temperatures *could* affect the frequency and or intensity of storms was not at all absurd.

Hurricane frequency and intensity might be scientific parameters of interest, but they are also military ones. The U.S. Navy spends millions of dollars per year on the matter whether a storm strikes the United States or not. Whenever a tropical depression forms in the Atlantic or Pacific Oceans, the U.S. Navy is watching, forecasting and planning. If a storm develops and tracks near ships at sea, those ships must be diverted away; if it approaches a port, a decision must be weighed as to whether the storm intensity will cause enough damage to warrant a sortie of all ships from the port to evade at sea. In light of the millions of dollars of losses that might occur if a ship takes damage topside from winds or windblown debris - or if it slams up against a pier or another ship – it may seem this decision is a "no-brainer." But ordering a sortie also costs millions of dollars in fuel, lost repair and upkeep work, and enormous amounts in human resources – especially if one considers the time crews already spend at sea and away from families. The admiral responsible for such a decision must weigh all factors before issuing the order; if an accurate forecast means that ships might be kept pierside and weather the storm without damage, millions of dollars are saved. If, however, the forecast proves less than accurate after a "no-go" decision is made… What is more, the safety of the Fleet during storm avoidance is not the only reason the U.S. Navy must pay attention to tropical storm activity.

Recent events have made it apparent that the U.S. Navy has a new role for its post-Cold War mission description – the ability to respond with humanitarian assistance after a natural disaster. This mission has

in reality been a long-standing one in the years since the Cold War ended, but was thought of in a different capacity when it was a matter of *foreign* assistance to places such as Somalia after a prolonged drought, or when the eruption of Mount Pinatubo in the Philippines inspired American assistance. After a massive tsunami devastated Indonesia and other islands of the Indian Ocean in late 2004, the United States Navy responded to the scene with an aircraft carrier and an amphibious expeditionary strike group that were on deployments geared to the conflict in Southwest Asia. Demonstrating the mission flexibility and logistical wherewithal to support a large humanitarian operation while trained and outfitted to conduct combat operations was no small feat. But response in this instance was just that – response; there was little warning that such a catastrophe was imminent and almost entirely coincidental that naval forces were near enough to respond in timely fashion. Moving additional assets into the region such as a hospital ship required many days to activate the vessel and deploy it thousands of miles to provide succor. It was also obvious that all capabilities were not equal for such missions; the aircraft carrier was nowhere near as capable of responding to this type of crisis as was the amphibious assault ship with its helicopters and amphibious vehicles and a battalion of embarked Marines. The humanitarian efforts were not lost on international observers – which was significant in that this assistance was rendered to a Muslim country while some sought to portray the ongoing conflict in Southwest Asia as a holy war between Christianity and Islam - nor were they overlooked by American military planners: the U.S. Navy possessed unique tools to assist in event of natural disasters.[223] It was a lesson learned that would be utilized much sooner and much closer to home than the United States Navy anticipated.

After spending the previous week ensuring that naval assets were ordered well clear of the widespread high seas advancing before Katrina, the author was ordered south from duties as Staff Oceanographer at Second Fleet Headquarters in Norfolk, Virginia once the storm had moved ashore. Having spent years on the Gulf Coast, he was familiar with the infrastructure and was deployed to serve as the eyes and local knowledge for the admiral serving as the Joint Force Maritime Component Commander (JFMCC) for the military operation that quickly formed into Combined Joint Task Force Katrina (JTF-K). Riding beside the

[223] Rhoda Margesson, *Indian Ocean Earthquake and Tsunami: Humanitarian Assistance and Relief Operations* (Washington, D.C.: Library of Congress Congressional Research Service, 2005), RL32715; Bruce Vaughn, *Indonesia: Domestic Politics, Strategic Dynamics, and American Interests* (Washington, D.C.: Library of Congress Congressional Research Service, 2006), RL32394.

JFMCC in the SH-60F, pointing out what the damage represented to coastal communities and where logistics might still be moved via alternate routes despite the loss of bridges and roads, the author was privy to most of the early response efforts that spanned from Bayou La Batre, Alabama west to the city of New Orleans.

Joint Task Force Katrina was an unprecedented military response to a domestic natural disaster, and one that confronted many obstacles including poor (surviving) communications infrastructure, unfamiliar interagency coordination, multinational response in U.S. territory, and concern on the part of JTF-K leadership for violating a historical domestic law known as *posse comitatus* that forbade the use of military forces in situations where civilian authorities normally exercised control. In the interest of saving lives, accommodations were made and compromises negotiated that paired civilian authority with military resources to overcome organizational disconnects and to meet the spirit of the law while still allowing the soldiers, sailors, airmen and Marines to help in the relief efforts. In fine military bureaucratic fashion, best practices and lessons learned were collected from all participants both during and after the event, and analyzed and reanalyzed to determine how to respond even more effectively in the future if the need should arise again. And that is where the U.S. military and especially the U.S. Navy finds itself at this writing one year after Hurricane Katrina – wondering whether it will be called into service after another tropical storm sweeps ashore in the United States or in some location in the Caribbean or Gulf of Mexico.

Because of their ability to move large logistical loads, make their own power and water, and serve as refueling and resupply points for helicopters when such facilities are unavailable in the wake of a storm, naval vessels are uniquely capable in providing response to storms that move ashore *from the sea* and devastate coastal areas. Hurricane frequency and intensity are not abstract matters of science to military planners, but matters that impact logistics and the availability of ships, airplanes and personnel maneuvering to follow a storm ashore. The ability to accurately forecast storms and the high winds and seas that surround them are essential to the planning and execution of a naval response to a tropical storm strike. Humanitarian Assistance/Disaster Response Tactical Memorandums were created for foreign and domestic response scenarios, and training began in earnest even before the record 2005 season closed.

Anticipating another busy time of it in 2006 after early predictions called for *seventeen* named tropical cyclones in another above-average season, military planners sought to exercise newly developed plans and inter-service and interagency relationships.[224]

Exercise Ardent Sentry mobilized elements of the armed services in May 2006 to work a mission that if not entirely new then at least was one that was now reemphasized and reinvigorated: Defense Support to Civil Authorities (DSCA). Interestingly enough, the scenario for Ardent Sentry depicted a strong hurricane passing down the Gulf Coast and moving ashore at Lake Ponchartrain... Responding to natural disasters had been established quickly as a new skill set for the United States military and especially in the case of hurricanes for the amphibiously-capable U.S. Navy. And if Dr. Emanuel was correct and global warming was indeed warming the seas of the tropical Atlantic and consequently elevating the frequency and intensity of hurricanes in the Atlantic basin, it was a skill set that likely would see more use in the future.

Seasonal forecasts for tropical cyclones are important for long-range planning, but much remains to be improved upon. The record 2005 Atlantic season is a recent and particularly pertinent example, and the very well known predictions issued by Dr. Bill Gray of the Colorado State University illustrate how difficult it is even with global circulation and climate models and supercomputer simulations to pin down natural phenomena. Dr. Gray's team predicted that the 2005 season would produce eleven named storms (about one more than an average season of 9.6 storms) of which six would reach hurricane strength (essentially the 5.9 average for a season). Fifty five named storm days were predicted of which twenty five were expected to be at hurricane strength (compared to 49.1 and 24.5 respectively for an average year). Three intense hurricanes were predicted to form lasting a cumulative six days (2.3 intense storms and five days of cumulative duration depict an average season). Overall, Dr. Gray's team predicted that for 2005, Net Tropical Cyclone Activity – a term that incorporated the other metrics to provide an intuitive estimate to compare interannual activity – would be fifteen percent higher than average.[225]

[224] William M. Gray and Philip J. Klotzbach, "Extended Range Forecast of Atlantic Seasonal Hurricane Activity and U.S. Landfall Strike Probability for 2006," 2005 (accessed February 7, 2006); available from http://hurricane.atmos.colostate.edu/Forecasts.
[225] Gray and Klotzbach, "Summary of 2005 Atlantic Tropical Cyclone Activity and Verification of Author's Seasonal and Monthly Forecasts," (accessed).

When the 2005 season finally drew to a close (in 2006!), there had been twenty eight named storms, fifteen hurricanes and seven intense hurricanes. There were over a hundred days of named storm activity, of which a fraction over forty-five days were of hurricane strength and almost seventeen were days that witnessed intense storm presence. Net Tropical Storm Activity was one percentage point below two hundred and fifty percent of an average season. In other words, 2005, a moderately above-average season according to long-range forecast estimates, turned out to be more than twice as active as one of the most respected hurricane researchers had predicted.[226] Much has been learned about atmospheric processes, yet there is still a great deal to learn; what is more given the inherent non-linearity of fluid systems there will *always* be an element just beyond the researcher's grasp. Feedbacks provide many avenues for developing systems to follow, and the essentially infinite combinations of inputs with respect to wind speeds and vertical shear, ocean temperatures, atmospheric moisture, the presence of land, the position of other systems and many other factors make forecasting tropical storm development and behavior at times seem only marginally more predictable than a crap-shoot. Time and again the best hurricane forecasters are stymied by the development or movement of a system, even with all the tools they have at their fingertips. And while it is important that forecasters develop new tools and methods for improving the accuracy of their predictions, it is also important that they maintain access to ones they currently have.

While seasonal hurricane forecasts may have something of a "roll-of-the-dice" sense to their accuracy, short-term forecasts are steadily improving. Once disturbances are noted in the atmosphere – either by perturbances in circulation models, visual evidence and parametric detection by sensors onboard satellites, or through telltale atmospheric measurements taken by instruments in regions of cyclogenesis – forecasters follow intently. Additional measurements are ordered from field stations in advance of developing systems, and specially outfitted aircraft are vectored over and through them to sample conditions and drop sensors directly into the atmosphere and the seas that feed their growth. Enormous resources are brought to bear, and forecast track and intensity accuracy has improved. Time honored rule-of-thumb estimates for operational use generally applied one hundred mile error arcs to a storm's forecast position for each twenty

[226] Ibid. (accessed).

four hour period of the forecast, graphically appearing as a cone of uncertainty from the last recorded position. Recent analysis of "superensemble" forecasts that blend features of many models indicate that this cone of uncertainty has almost been cut in half in recent years.[227] But average performance does not suffice for actual performance in any given storm situation where lives are on the line and property damage into the billions of dollars threatens; here any tool in the toolbox is critical to ascertaining the track and intensity of a storm.

For naval oceanographers contemplating the best actions to keep the fleet safe, it is a complex mental algorithm that balances storm track and intensity, the onset of destructive winds and high seas, geographic constraints that delimit sortie options and evasion, material condition and readiness of vessels as well as seakeeping limits while underway, operating speeds under various scenarios of winds and seas (beam seas affect vessels differently from oncoming or following seas), and any number of operational constraints that sometimes dictate that naval vessels cannot deviate in their course or position because of the imperative of their mission. Tropical storms can move at speeds that match or exceed the best speeds that ships can muster, so determining their path and strength is critical; high seas propagate well in advance of storms, and ships that might evade at twenty knots in calm seas could be lucky to make twelve knots if rising seas impede their progress. In the past uncertainty for the motion of the storm for vessels potentially in its path was something akin to a game of chicken; until persistence of track or certain geophysical commitments like recurvature and acceleration showed the path of the storm, vessels waited as long as possible to ensure that their choice of evasion would open their distance to the storm instead of close the range if the storm behaved errantly. Now, in 2006 and for the foreseeable future, vessels have an additional challenge: deliberately "playing chicken" with a storm to avoid its fury while staying as close as possible so that they might move in behind the storm to provide assistance to those left stunned by its passage ashore.

Crossing the southern Florida marshes after inflicting an initial round of damage to the Miami area, Hurricane Katrina was predicted to move west over the waters of the Gulf of Mexico and then northwest

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[227] Mrinal K. Biswas, Brian P. Mackey, and T.N. Krishnamurti, "Performance of the Florida State University Hurricane Superensemble During 2005," in *60th Interdepartmental Hurricane Conference* (Mobile: Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2006).

toward the Florida panhandle somewhere near Apalachicola. Discussing the situation with other oceanographers, the author knew that another possibility existed that made this relatively moderate Category One storm something about which to be very concerned. Color-coded thermal imagery showed the Loop Current that intruded into the Gulf of Mexico in a rainbow arc that Katrina would pass over if her track tended at all south of west instead of its predicted west-northwest track. The Loop entered the Gulf of Mexico between Cuba and the Yucatan peninsula and arched towards the Gulf Coast before bending its warm waters through the Straits of Florida. A warm core eddy that had shed from the Loop lay just to the northwest in line with the Mississippi Delta at the birdfoot coastline of Louisiana, in the thermal image appearing like a colorful bullseye stepping stone from the Loop for a hop and skip over the *relatively* cooler waters of the northern Gulf. What made the Loop and the eddy important was not just that their sea surface temperatures would be conducive to evaporative forcing of the hurricane's convective activity; what was important was their *depth*. When a hurricane passes over an area of ocean, the great churning of the waters often elevates colder water from depth; in satellite infrared imagery this makes it appear that a storm leaves a cold wake in its trail. This colder water helps to diminish the power of the storm similar to if the hurricane had tracked over a region of cold water or a cold core eddy. If Katrina were to track over the Loop, however, and the warm eddy beyond it would be less likely to help stem its own growth by upwelling colder water since these features held warm water from the surface to depth.

The discussion among naval oceanographers as Katrina tracked across the Okeefenokee remarked upon how important it would prove if her path were 270 (degrees true) or 240. If Katrina tracked offshore just to the north of Naples the waters were warm, but not as warm and deep as the Loop; if Katrina moved southwest of Naples the storm would spend less time over land because of the shape of the Florida coastline and track straight into the region where the Loop entered the Straits of Florida. In the satellite imagery fears were confirmed…Katrina tracked closer to 240 and directly over the warmest water in the Gulf of Mexico where it exploded into a Category Five storm before beginning a long northwest arc that allowed the storm to gain additional energy from the stepping stone warm eddy and slam into the Gulf Coast after following just about the optimal track (for storm development) possible. When Hurricane Rita entered the Gulf of Mexico a month later on a more southerly track, it also tracked and intensified to

Category Five across the Loop and the same warm core eddy which had drifted to the southwest after Katrina's passage, delivering a follow-up blow to an already punch-drunk Gulf Coast populace. Later in the season, Hurricane Wilma completed the "trifecta" by also strengthening to Category Five over the Loop Current.[228] While all of these storms decreased in intensity before making landfall, their periods of higher intensity at sea in a constrained ocean basin were of importance in many ways to both vessels at sea trying to avoid their wrath, and populations ashore cowering in fear before them.

Before Katrina surged into the central Gulf of Mexico, the ships of the Second Fleet were ordered clear of potential impact sites along the Gulf Coast. Working with the Optimum Track Ship Routing Service of the Naval Meteorology and Oceanography Command's (CNMOC) Naval Maritime Forecast Activity (NMFA) in Norfolk, the author and forecasters working with him at the Fleet Headquarters determined tracks that were approved by the admiral in command for vessels to avoid the storm. Twenty foot seas built steadily well over two hundred miles in a broad arc ahead of Katrina's advancing position throughout the Gulf of Mexico, and ships were ordered west and south to place them clear but also where they might escape through the Yucatan Channel if Katrina's trajectory flattened and the storm moved instead towards Texas instead of Louisiana and Mississippi. The decision to sortie and selection of an evasion point were made well in advance of the storm's approach to allow the ships to evade the advancing seas; the cone of uncertainty dictated this caution, but it proved serendipitous afterwards. One vessel, *USS BATAAN*, a *WASP*-class amphibious assault ship with embarked helicopters was ordered to a position well southwest of Louisiana's birdfoot delta to wait for Katrina to pass ashore, and then was ordered to make best speed through the diminishing seas in the storm's wake to allow its helicopters to launch if necessary to assist in the storm's aftermath.

With a large number of damaged oil platforms and potential underwater hazards, *BATAAN*'s passage was not purely a matter of time-distance at a flank bell. While in retrospect it appears obvious that this was a common sense decision and maneuver to rush to help people in dire need, it was not at all ac clear at the time; no recent storm had so devastated the United States to require an amphibious response - and placing a

[228] Shay, Jaimes, Uhlhorn, Brewster, Mainelli, Lillibridge, and Black, "Hurricane Trifecta: Katrina, Rita and Wilma Interactions with the Loop Current."

valuable warship in proximity to a storm that could easily put it at the bottom was not without risk. Nevertheless, when Katrina moved ashore, *BATAAN* moved northeast and her helicopters were available to assist in recovery efforts hours after Katrina moved ashore. On the ground at Naval Station Belle Chasse near New Orleans a few days later, the author noted that some of *BATAAN*'s helicopters numbered among the dozen or so that represented almost the entire search and rescue effort ongoing in the flooded city. A few days afterwards, one could not look around at Belle Chasse without seeing dozens of helicopter among the hundreds of aircraft that descended on this rescue outpost by the week's end (Katrina struck on a Monday), but in those first few days every aircraft mattered critically to the ongoing effort to save lives. Placing *BATAAN* in a position to respond to a disaster of this nature and magnitude foreshadowed future considerations for using such assets as an established rather than *ad hoc* mission of the U.S. Navy.

What's Important is More than Skin Deep…

The power of an ocean storm varies approximately with the cube of the wind speed.[229] Intensity forecasts become critical when storms threaten populated areas, not only for the damage they can physically inflict, but because people who live in areas where storms are not uncommon become complacent when the cyclones approach but often miss. Just a month before Katrina changed New Orleans forever, Tropical Storm Cindy narrowly avoided the Crescent City. The population barely blinked. A sociology professor from Louisiana State University summed it up, "There's a reason New Orleans has a drink called the hurricane. The culture here is 'we don't evacuate.'"[230] Although it had been threatened many times, New Orleans always managed to dodge the bullet. A poll by the University of New Orleans (prior to Katrina) indicated that 62 percent of New Orleans' million-plus residents would ride out a Category Three storm.[231] When it crossed the birdfoot delta and just east of the city, Hurricane Katrina was a Category Three storm. The situation was much the same just to the east in Mississippi. Many residents had witnessed the worst that nature had to offer (previously) when back in August 1969 Hurricane Camille

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[229] Emanuel, "Anthropogenic Effects on Tropical Cyclone Activity," (accessed).
[230] Quoted in Dan Gilgoff, "Big Blow in the Big Easy," *U.S. News & World Report*, July 18, 2005.
[231] Ibid.

surged ashore as a Category Five storm with winds above one hundred and eighty miles per hour and storm surges that reached over twenty feet.

Everywhere along the Gulf Coast was some subtle (and a few not so subtle) reminders of Camille from decades before. It was a topic that often wended its way into conversation: where the person had been, how long it had taken until utilities were restored, or having known someone who was lost. Curb cuts in sidewalks that led to nowhere but an empty lot were silent reminders of what had been. A kitschy tourist souvenir shop in a beached tugboat, *S.S. Camille*, greeted visitors along Highway 90 in Gulfport. One would have been hard-pressed not to have received a Camille report when looking at real estate – this house survived the storm with so many feet of water, or that one was built on the slab of one lost to its surge. The high water mark of the storm was traditionally – if not actually – the elevated rail bed of the train tracks that paralleled the coastline a few blocks in from the beach. Houses north of the tracks survived generally intact with perhaps some water, but nothing like the devastation south of the rail line; conservative home buyers bought north of the tracks. Camille lore was as much a part of the Gulf Coast as live oaks and seafood gumbo. Residents were not at all uncomfortable when storms threatened; after a Category Five, what more could be done to them? While the sheer devastation of Katrina is attributable to the storm's intensity and storm surge, the human element of the disaster is attributable much more to the emotional legacy of the previous benchmark, Camille. One must wonder if a new generation of Gulf Coast residents will not make evacuation decisions based upon their experience with Katrina…if so, military responders will undoubtedly have their hands full since so many factors make storms entirely different experiences, not the least of which is the most common convention that labels them according to the intensity of their wind fields, the Saffir-Simpson scale.

Since the power of a hurricane varies with wind speed, it would appear acceptable to label a storm according to various breakpoints in this parameter, which is what the Saffir-Simpson scale does. The scale provides divisions between storm categories at seventy-four miles per hour, ninety-six miles per hour, one hundred and ten miles per hour, one hundred and thirty-one miles per hour, and above one hundred and

fifty-five miles per hour.[232] But the scale does not strictly tie the heights of expected storm surges of ocean waters to these categories, and it is for this reason that disaster relief planners have some considerable cause for worry. If local populations consider only the category of the storm, they may become complacent and decide to ride out the storm in vulnerable areas. The problem here is that storms often decrease in intensity near landfall for any number of incompletely understood reasons but at least in part because of shallower ocean depths (from which to draw thermal energy), the impact of convective feeder bands moving ashore prior to the main landfall of the storm where they have no waters from which to draw their energy, and wind patterns that are different over land with its frictional effects than over ocean waters. Yet while storms are still at sea, it is their intensity there that raises waves and pushes water towards the shore where shallowing bathymetry leaves this lens little place to dissipate except over the shoreline ahead of the storm. In ocean basins such as the Gulf of Mexico where the shape of the coastline further focuses the surge ahead of a tropical storm, higher surges than might otherwise be formed are possible. When the storm passes and winds shift and no longer push water in the direction of the storm, the surge quickly recedes, but the devastation and death associated with tropical cyclones is largely related to the action of storm surges.

When intensity diminishes and this information is broadcast to residents in the path of the storm, there is a lower expectation for damage from winds…and from storm surges that are loosely coupled in the Saffir-Simpson scale to categories in broadly descriptive terms. Category One storms imply "some coastal flooding and minor pier damage" is possible; with a Category Two storm, "flooding damages piers, and small craft in unprotected anchorages break moorings;" at Category Three, "Flooding near the coast destroys smaller structures with larger structures damaged by floating debris;" in a Category Four storm, flooding may cause "major erosion of beach areas…[and]…terrain may be flooded well inland;" Category Five storms bring more severe consequences, "Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas may be required."[233] While the Saffir-Simpson scale does not supply ranges in flood elevations, the National Oceanic and Atmospheric

[232] "Hurricane Basics," 1999 (accessed February 7, 2006); available from www.nhc.noaa.gov.
[233] Office of the Federal Coordinator for Meteorological Services and Supporting Research, *National Hurricane Operations Plan* (Washington, DC: U.S. Department of Commerce/National Oceanic and Atmospheric and Administration, 2006), Appendix E.

Administration provides estimates of four to five feet, six to eight feet, nine to twelve feet, thirteen to eighteen feet, and greater than eighteen feet to Category One, Two, Three, Four, and Five storms respectively.[234] The danger in loosely coupling surge estimates to wind intensity is that the surge may have been built by a much more powerful storm than the one that is at that moment crossing the beach, and the height of the surge more indicative of the stronger storm. For those expecting a Category Three level surge such as might have been anticipated in the last few hours before Katrina went ashore in Mississippi, the arrival of a surge more akin to that expected with a Category Five – which proved to be the case with Katrina which brought unprecedented surges of greater than thirty feet – would be disastrous.

While it might seem incongruous given that hurricanes are ocean storms fueled by the thermal energy stored in surface waters, it was only relatively recently that ocean heat content became consistently part of the analysis for tropical cyclone intensity forecasting. "Beginning in 2002, daily Ocean Heat Content (OHC) analyses have been generated at the Tropical Prediction Center (TPC)/National Hurricane Center (NHC)...[and]…used qualitatively for the official NHC intensity forecast, and quantitatively to adjust the Statistical Hurricane Intensity Prediction Scheme (SHIPS) forecasts." The use of ocean heat analyses was shown to "aid in intensity prediction where both synoptic and mesoscale features exist." The OHC analysis improved intensity estimates for more intense Category Five storms by up to six percent on average, and as much as twenty percent in individual storms. On the whole, hurricane researchers concluded that "knowledge of the ocean structure is fundamental to accurate forecast intensity changes of cyclones."[235]

The action of hurricanes on ocean thermal structure is made evident by the cold wakes left by the passage of storms; equally important, however, was that "atmospheric response to the pre-storm forcing by warm and cold features" needed to be taken into account.[236] Ocean profilers deployed by NOAA aircraft before and after Hurricane Rita demonstrated that the warm core eddy which Katrina had passed over had

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234 Todd Spindler and Jack Beven, "The Saffir-Simpson Hurricane Scale," 1999 (accessed April 01, 2001); available from http://www.nhc.noaa.gov/aboutsshs,html.
235 Michelle Mainelli, Mark DeMaria, Lynn K. Shay, and Gustavo Goni, "Application of Oceanic Heat Content to Operational Forecasting During the 2004 and 2005 Hurricane Seasons," in *60th Interdepartmental Hurricane Conference* (Mobile: Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2006).
236 Shay, Jaimes, Uhlhorn, Brewster, Mainelli, Lillibridge, and Black, "Hurricane Trifecta: Katrina, Rita and Wilma Interactions with the Loop Current."

advected westward and shallowed; what was more a cold core eddy had moved between the Loop and the weakening warm core eddy. After strengthening to Category Five over the Loop Current, Rita diminished in strength to Category Three over the cold core eddy; tracking over the weaker warm core eddy before making landfall Rita did not reintensify but maintained Category Three strength until moving ashore.[237] Analysis of intensification of Hurricanes Katrina and Wilma also showed that the storms intensified to Category Five strength over the Loop Current (and a warm core ring shed from the Loop in the case of Katrina) and weakened in intensity after moving over colder waters beyond the feature.[238]

Mesoscale ocean features were thus important to the intensity of the hurricane. While these features were sampled *in situ* by profilers dropped from NOAA reconnaissance aircraft, they were also sensed and tracked by *satellite altimeters* on the GFO and JASON satellites. Together these forms of data allowed the investigation of the importance of mesoscale ocean features to the intensification of three of the most powerful storms ever recorded in the Atlantic basin, "*In situ* an satellite-based measurements [altimetry] support the hypothesis that the LC [Loop Current] complex played an important role on the rapid deepening of Katrina, Rita, and Wilma as the storms passed over the eastern Gulf of Mexico."[239] Infrared sensors on other geostationary and polar-orbiting satellites might provide a thermal signature for the Loop Current and it's eddies, but satellite altimetry was required to determine ocean height and consequently the vertical structure of the features in order to determine heat content which was essential to determinations of intensification.

Successful modeling of tropical storm development in this region depends on this sea surface height data, "In particular, the numerical weather prediction models must be able to incorporate and simulate properly the Loop Current cycle, including area and depth spanning, ring formation and shedding, and instabilities triggered during the ring separation sequence. This will have important consequences in

[237] Benjamin Jaimes, "Influence of the Loop Current Ocean Heat Content on Hurricanes Katrina, Rita, and Wilma," 2006 (accessed Feburary 7, 2006); Shay, Jaimes, Uhlhorn, Brewster, Mainelli, Lillibridge, and Black, "Hurricane Trifecta: Katrina, Rita and Wilma Interactions with the Loop Current."
[238] Mark DeMaria, *NPOESS Applications to Tropical Cyclone Analysis and Forecasting* (Fort Collins: Cooperative Institute for Research in the Atmosphere / Colorado State University, 2006).
[239] Jaimes, "Influence of the Loop Current Ocean Heat Content on Hurricanes Katrina, Rita, and Wilma," (accessed).

coupled [ocean-atmosphere] operational models at the national centers."[240] The newest model under development at the National Center for Environmental Prediction for utilization in 2007 after operational evaluation during the 2006 season, the Hurricane Weather and Research Forecast system (HWRF), is a coupled atmosphere-ocean model that is "being designed to address the intensity, structure, and rainfall forecast problem in addition to advancing wave and storm surge forecasts."[241] If this and other forecast models are to be successful, data to initialize their subroutines for oceanic heat content will be required; what remains to be seen is whether an altimeter will remain on orbit to provide this data.

"When You Get to the Fork in the Road, Take It!"[242]

After the relatively straightforward challenges that the United States confronted throughout the Cold War in opposing the naval strategy of the Soviet Union, the post-Cold War is a considerably more complicated security environment. Immediate post-Cold War challenges were still perceived initially as state-centric; operational focus shifted from the open ocean to the shallower littoral, but concentrated on the use of naval forces engaged against other smaller navies; projecting power across the shoreline against adversaries; or in some cases conducting humanitarian relief missions or non-combatant evacuations of personnel from amidst someone else's conflict. Over the last five years, security concerns have been increasingly focused on the Global War on Terror (GWOT), a conflict that is expected to be drawn out to such a degree that in some circles it has become known as the Long War. Specific naval aspects of this conflict are even more variable than the various littoral scenarios envisioned in the immediate aftermath of the decades-long conflict that dominated the latter half of the twentieth century: interdiction of terrorist cargoes of weapons and explosives, and of seaborne operations that finance terrorism ashore; countering a renewal of modern forms of piracy off the coast of Africa and in the Indonesian and Philippine archipelagos; and assistance for nascent navies in support of foreign internal defense are newer mission sets that underpin the GWOT or Long War responsibility for the U.S. Navy.

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240 Ibid. (accessed).
241 N. Surgi, S. Gopalkrishnan, Qingfu Liu, Robert Tuleya, and W. O'Connor, "The Hurricane WRF (HWRF): Addressing Our Nation's Next Generation Hurricane Forecast Problems," in *60th Interdepartmental Hurricane Conference* (Mobile: Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2006).
242 Berra, "The Quotations Page," (accessed).

These types of new missions are even more removed from major combat operations (MCO) that Cold War strategy envisioned or that in more limited fashion were exercised against Iraq in Desert Storm and its more recent incarnation from 2003 to the present time in that same region. All the same, naval emphasis on MCO remains a priority at least regionally in Southeast Asia where uncertainty about Chinese objectives persists as well as inconsistent – or perhaps rather consistently belligerent - behavior on the part of North Korea imperils U.S. interests and strategic partners in the region, as well as in Southwest Asia where growing Iranian naval capabilities threaten U.S. interests in the Straits of Hormuz. Naval aspects of state-sponsored terrorism loom somewhere on this horizon; analysts fear that submarines may eventually be utilized to deliver terrorists or weapons of mass destruction to the shores of the United States or her allies. With all of these considerations, environmental constraints to naval operations do not leap to the forefront for naval planners; but upon even modest reflection, the intersection of environmental issues with naval challenges – those discussed above and others – is both widespread and multifaceted.

As in earlier times this influence is felt primarily in addressing operational and tactical levels of naval warfare: environmental influences intersect with overall operational strategies for implementing national strategic objectives such as power projection and sea control in areas that involve theater-wide antisubmarine warfare, and newer sea-basing strategies are inherently dependent upon environmental constraints for operations. And as always, the influence of the ocean environment remains an insoluble consideration at the tactical platform-versus-platform level for both surface and undersea warfare. While not oriented towards combat, newly established doctrine to support Humanitarian Assistance / Disaster Response (HA/DR) operations in the wake of natural disasters is fundamentally dependent upon environmental factors. And although its impacts remain speculative, global climate change looms on the horizon across strategic, operational, and tactical levels of naval warfare focus. The manner in which the United States Navy will address all of these challenges is still open for debate and for events to unfold, but it is apparent that ocean science will play an integral role in addressing environmental aspects of them. Like so many other things in an increasingly interconnected and interdependent 21st Century world, aspects of security – and particularly naval aspects – are linked in many ways to the natural environment.

As something of a holdover from the Cold War, contemporary naval concerns over submarine warfare represent some of the most direct environmental challenges for the United States Navy. The ocean remains essentially opaque to most means of detection, and the stealth and lethality of submarines have increased while the battlespace has shifted from the open ocean to the geophysically more challenging coastal shallows - making this threat every bit as difficult as the Soviet one from years before. The growing proliferation of submarine technologies to potential adversaries, together with the increasing operational capabilities and number of assets put to sea by more traditional opponents such as the People's Republic of China and the Democratic People's Republic of Korea, maintain antisubmarine warfare as an essential mission set for U.S. naval forces. While the situations are different and do not represent strategic threats as did the Soviet ballistic missile forces, operationally and tactically submarine threats in the Western Pacific, the Taiwan Straits, the Yellow Sea and the Sea of Japan are obstacles to U.S. maritime strategy in those regions. The aircraft carrier strike groups which represent the U.S. Navy's primary means of power projection can not operate freely when submarine threats are on the prowl. A similar threat is envisioned in the Straits of Hormuz at the opening of the Arabian Gulf as Iran improves its undersea warfare capacity through the purchase of diesel submarines and gains experience in operating those boats at sea. To combat emerging undersea threats, research and testing of low frequency active sonar - which had initially been designed to oppose the quieter Soviet nuclear boats that became operational near the end of the Cold War - was reinvigorated, and soon came to be considered the lynchpin for broad area detection against increasingly silent targets that operate in areas that are acoustically variable.

The statement that low frequency active sonar is considered the lynchpin of present-day antisubmarine warfare requires a caveat. LFAS is a strategy that faces immense legal and political pressures as a result of environmental opposition to testing and operational use that have since further complicated issues by entraining more traditional ASW mid-frequency sonars into the disputes. Aside from the impact this portends for the United States for its antisubmarine warfare strategies, this legal and political conflict may hold enormous implications for even broader naval strategic and operational considerations if it reaches a critical mass capable of influencing international environmental law in areas relevant to the Law of the Sea.

Changes or new developments in international law, or legislation that could be enacted by countries to protect environmental resources in their Exclusive Economic Zones, might severely hamper the U.S. Navy's efforts to utilize either its low frequency or medium-range frequency sonars for antisubmarine warfare, and by extension the areas that the United States Navy operates. A great deal of that remains speculative and also depends on whether the U.S. would stand behind sovereign immunity principles for warships operating under standard practices or alternately seek to claim national security exemptions for its activities even if that meant inflicting damage to its relations with other states.

With antisubmarine warfare once again climbing the priority list for the United States Navy after years of lesser emphasis, the controversies that ensued over the use of active sonar have largely dominated the discussion of late; but antisubmarine warfare also depends heavily on technologies and techniques to environmentally characterize the underwater battlespace. This is critical for active sonar scenarios for determining the influence of the environment on sound propagation, and for passive sonar operations which also depend on understanding acoustic propagation conditions and which must distinguish scant noises emanated by adversaries from the background ambient noise of the oceans which is made up of many sources. Both the Southeast and Southwest Asian theaters that have become of increasing concern are regions of oceanic variability where mesoscale features influence greatly the acoustic properties of the water column. Effective antisubmarine warfare operations must account for this environmental variability and leverage knowledge about the physical operating environment to efficiently pursue ASW campaigns to assure force protection, to maintain open routes of communication and to achieve broad areas of sea control. Integrated environmental strategies that couple data collection, ocean characterization and forecast modeling, and weapons and sensor optimization to environmental influences are keys to successful antisubmarine warfare efforts. But precisely at a time when environmental challenges are so apparent and difficult because of a shift from the open ocean to littoral environments, tools that ASW strategies depend upon will come into question.

Ocean modeling which drives tactical decision aids is dependent upon data initialization that comes from satellite remote sensors, especially in regions considered "denied areas" under the control of

adversary nations. MODAS (Modular Ocean Data Assimilation System), the current progeny of ASWEPS, relies on large scale ocean models to determine sea surface boundary conditions from which it predicts the three dimensional thermal fields that determine acoustic propagation for sonar tactical decision aids; and these global ocean circulation models utilize satellite data to initialize sea surface height and would otherwise be forced to rely on climatology – at a time when the validity of historical environmental datasets have come into question because of uncertainties over global climate change – to determine model boundary conditions. The sensor that provides this data – the satellite altimeter – is destined to be lost to military usage unless some action is taken in the near future to avoid an altimetry gap that will occur if future sensors are not designed and flown on upcoming satellite missions. For a service still concerned with antisubmarine warfare in the post-Cold War, the United States Navy should be alarmed over the potential loss of critical satellite remotely sensed altimetric data. With greater reliance on active sensors, some of the finesse of environmental characterization becomes overshadowed; "more power" can in some instances burn through acoustic clutter to find an underwater target. The key to effective antisubmarine warfare operations is balancing passive and active searches, and environmental effects remain a factor which should not be underestimated or overlooked. But as is the case fro altimetry and other important programs, naval priorities must be balanced with other service priorities in competition for Defense dollars; time will tell whether or not this concern is elevated above some of the more immediate problems posed by pressing concerns with the Global War on Terror.

Global Climate Change is one of the most contentious international issues of the present day. Although it remains more a matter of science and public policy than a security consideration, growing appreciation for the potential impacts of GCC – especially in the field of *abrupt* climate change – highlights various ways in which this environmental issue permeates military considerations from the strategic down to the tactical level of warfare. Scenarios such as that developed by the Department of Defense's Office of Net Assessment may remain too speculative or spectacular to garner serious attention in some security circles; but they should not be entirely discounted. We may never know how societies would react to climate-induced situations of dire need bordering on survival; no matter how post-apocalyptic scenarios of substantial and abrupt climate change may seem, we know from the historical record that there remains at

least the potential for them to occur. Reflecting on days spent in New Orleans the week after Katrina had flooded the city and forced its general evacuation, the author is reminded of the looted storefronts and lack of civil authority to the point that martial law was imposed; the research that Randall and Schwartz based their projections upon is not without precedent or additional evidence: when humans face situations of survival, at least *sometimes* they raid.

With scenarios for abrupt climate change centrally concerned with changes to the thermohaline circulation of the oceans – and the North Atlantic in particular – this area of environmental uncertainty has specific and concrete influences on the operational and tactical conduct of naval warfare. Some of these impacts are restricted to the operating areas of the North Atlantic and the Arctic, areas that held particular relevance during the Cold War but that may not presently be of the same significance save possibilities for tension and potential conflict over mineral rights in an increasingly accessible Arctic, or over the usage rights of nations desiring to take advantage of possible polar routes between the Atlantic and Pacific. But climate change instigated by oceanic processes in the North Atlantic may also affect other regions of the globe because of atmospheric and oceanographic teleconnections, possibly creating conditions conducive to conflict that might drag the United States into the mix - and consequently naval operations to support such activities. But teleconnections can also alter the physical ocean operating environment itself for many aspects of naval interest, and especially for antisubmarine warfare (which was just discussed as a potential problem area for the U.S. Navy as a result of the pending loss of altimetric data to drive predictive models and TDAs, and because of constraints placed on active sonar operations) in areas near the Arabian Gulf or in the Western Pacific that might more reasonably be considered near-term hotspots for the United States Navy as opposed to regions bordered by allies and trading partners.

Resolving climate change therefore is still very relevant to present day security concerns; however, the same challenge that is posed to ASW by the loss of satellite altimetry threatens climate change research in general and as a matter of strategic security concerns beyond accounting for oceanic changes that impact the tactical prosecution of undersea threats. The global ocean circulation models that initialize antisubmarine warfare tactical decision aids are also the ones that scientists use for *climate change*

projections. Forecasting ocean conditions to anticipate changes becomes problematic when predictive models must be initialized by historical climatologies rather than ambient conditions because of a lack of near-real time remotely sensed data! What is more, if theories of abrupt climate change hinge upon resolving mesoscale changes in and around thermohaline downwelling sites near the Labrador Sea and the GIUK Gap, the optimal synoptic method to monitor this area with sufficient spatial resolution and parametric precision will soon to be out of commission. With the potential for abrupt climate change to take place over the span of only a few years, an altimetry gap might prove to be more than a passing antisubmarine warfare worry for the U.S. Navy…

If only for the billions of dollars of damage hurricanes inflict (almost) annually upon the United States, they are a concern of national proportions. And for their longstanding impact upon the safety of naval vessels and coastal installations, they have a lengthy and storied history as a matter of naval attention. But in addition recently they have become an even more dynamic influence upon naval operations - forcing considerations of naval planning to account for ships, aircraft, personnel, materiel and logistics readiness, and multiple avenues of interservice and interagency coordination in the event of a hurricane landfall in the United States or some neighboring nation as a matter of Humanitarian Assistance / Disaster Response (HA/DR) and Defense Support of Civil Authority (DSCA). All the while, tropical cyclones remain the subject of limited understanding and predictive capacity. The National Hurricane Center expected with eighty percent likelihood that 2006 would be an above average hurricane season as part of "a continuation of above normal activity that began in 1995."[243] As of the present writing there are still some weeks to go in the 2006 season, but the NHC has steadily backed away from this aggressive outlook as the season has progressed with fewer storms thus far than anticipated. The 2006 tropical cyclone season (to date) is a good example that even a multi-year upswing in general hurricane activity is no guarantee in predicting any particular year's activity; in the midst of this same multi-decadal "above normal activity" period no hurricanes made landfall in the continental United States in either 2000 or 2001. Every season, every storm must be taken on its individual merits and tracked diligently from cyclogenesis to when it becomes extra-tropical.

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[243] "NOAA: 2006 Atlantic Hurricane Outlook," 2006 (accessed May 22, 2006); available from http://www.cpc.ncep.noaa.gov/products/outlooks/hurricane.shtml.

Hurricanes are monitored directly by a broad suite of sensors onboard satellites and that are carried by specially outfitted aircraft as well as emplaced on buoys at sea and scattered throughout terrestrial areas within regions of hurricane cyclogenesis. But hurricane predictive forecasts are also based on the use of global numerical atmospheric and oceanographic models that are initialized by data from some of these remote sensors. A primary environmental consideration in the prediction of hurricane development and intensification is the accurate depiction of mesoscale ocean thermal content – essentially the same information that forms the lynchpin of ASW TDAs and that is important for research into abrupt climate change. And once again, the primary sensor for this determination is the satellite altimeter - the impending loss of which has now been discussed repeatedly and in some detail. Accurate intensity forecasts are necessary for ships to avoid the high winds and seas in front of tropical cyclones, but now also so that vessels may shadow the storms as close as permissible in order to provide HA/DR and DSCA response in the storm's wake.

The lack of altimetry does not mean that naval vessels *will not* execute their missions regardless…for the Navy operates daily under considerations of operational risk management that balance hazard and reward and the creation of various mitigating strategies so that missions still can be executed in the most efficient manner possible. But the pending loss of information affects storm modeling efforts in two critical ways: the loss of altimetry data implies the reversion of global circulation models to climatological history with subsequent loss in predictive power; and strategies to resolve intensification trends when storms approach mesoscale oceanic features similarly lose fidelity in ways that might be considered non-linear to the outcome because of the cubic relationship between wind speed and the power of a tropical storm. Flying an altimetric sensor on a satellite does not guarantee capability when it comes to tropical storm forecasting - and most certainly does not imply that damages from an ocean storm could be entirely avoided – but as a critical tool for the estimation of storm intensity and the initial prediction of storm cyclogenesis it is a very important instrument to lose when it comes to the study of tropical cyclones.

It strikes the author as ironic that the preceding paragraphs discuss present day naval environmental challenges that all involve in some fashion the determination of the structure of the oceans on the mesoscale. Of course the reason these relationships are discussed in the present work is because of the tactical importance of mesoscale ocean features to antisubmarine warfare scenarios, and because mesoscale ocean processes determine such a large percent of energy transfer and circulatory variability in the ocean environment making them particularly significant for climate change (as well as hurricane cyclogenesis and intensification…); between them this more traditional naval threat and more speculative oceanic challenge are two of the primary security questions for naval operations in the present day. But the irony mentioned above in part stems from the fact that the first academic work the author accomplished in the field of oceanography almost twenty years ago was to analyze mesoscale ocean variability using the satellite altimeter flown on GEOSAT - with not even an inkling that his present day research would wander somehow back to that rather esoteric interest of the field. Yet it also is ironic that each of these areas depend so much on the threatened technology of satellite altimetry to provide information to investigate relevant mesoscale ocean features which to some degree could be resolved by another technology that was discussed earlier - and that was the catalyst for the research for writing the preceding chapter – the swords-to-plowshares civil ocean science application of low-frequency active sonar known as acoustic tomography.

Acoustic tomography and satellite altimetry became viable tools for the study of ocean variability because of the importance of the original uses of the technologies for antisubmarine warfare. But coincident with the time both were shown to be important technologies for the study of climate change, each became threatened because of decreased criticality of antisubmarine warfare at the end of the Cold War – altimetry through a more straightforward cost-benefit requirements analysis, and tomography through a more roundabout way in which security threats were made secondary to concerns about environmental impact. But this may need to be revisited. The U.S. Navy is moving towards a future that is both more uncertain with respect to extant traditional naval threats such as submarines, and with regards to speculative non-traditional threats such as climate change. Unless the Navy resolves the legal environmental controversies over LFAS/acoustic tomography or the budgetary concerns that grounded

future satellite altimeters, it will be less prepared to engage either form of environmentally dependent challenge at a time when they have grown in importance. While not completely interchangeable as data sources - altimetry and tomography have relative strengths and weaknesses related to temporal and spatial coverage - either would be better than neither; until some better technique is discovered, LFAS remains the optimal method to extend the range of detection for quiet modern nuclear and diesel submarines. Like déjà vu all over again, the U.S. Navy finds itself at a juncture where oceanic environmental challenges to security have arisen for which ocean science offers at least a means to address them…but which also have ramifications for security in areas entirely unrelated to the original concerns. Sometimes when encountering such a fork in the road, one must just take it.

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ΨΨΨ Chapter 6 Common Threads of a Consilient Fabric ΨΨΨ

The case studies presented in *Beyond the Water's Edge* span the history of ocean science and identify linkages between the marine environment and security that were made – and continue to be made – throughout the development of oceanography as a scientific endeavor. In the process, these accounts illuminate more generally in some measure the range of variables and scenarios that can be considered as matters relevant to the field of environmental security beyond the most prominent focal point that has been explored by other authors to date in this emergent subspecialty of political science: the possibility that environmental issues might instigate conflict. In each of the case studies the importance of environmental parameters to tactical and operational challenges led to their securitization – their identification as matters to be investigated and or monitored in order to address naval requirements – where they might not otherwise have received either the same level of attention or funding. Once these parameters became the focus of scientific interest in this fashion, subsequent research led to other considerations of relevance from a security perspective that in some instances surpassed the original matters in question as issues, challenges or concerns.

No strict path between environment and security linkages is *exclusively* determined through these case studies - which may be entirely appropriate considering the non-linearity of feedbacks that were identified in these accounts. Nevertheless, the cases demonstrate that an underappreciated process for linking the environment and security has been the importance of environmental variables for their impacts on military – in these instances naval – operations. What is more, the complexity of the variables, linkages and feedbacks that take place suggests that interdisciplinary expertise across multiple layers of analysis – consilience - is critical to understanding how factors interrelate in order to understand the processes underway and to provide some measure of explanatory power to what has occurred and the nature and extent of the ramifications for the future. Perhaps more now than ever, situations with relevant political, economic, social, cultural *et al* aspects that are further intertwined with various complicated and or uncertain *scientific* facets make integrated interdisciplinary analyses and approaches more appropriate and necessary in an increasingly globalized and interconnected world. The subtleties that emerge when

identifying the environment as an element of a security issue from a consilient approach - whether as cause, catalyst, consideration or consequence – require the analyst to broaden perspectives; the pervasiveness of environment-security linkages also suggests that for many situations one of the central questions that should be posed is transformed from one that asks whether and how the environment may be considered a factor…to whether and how it is not.

In the introductory chapter to *Beyond the Water's Edge*, the author suggested that environmental security should be divided into discrete areas to clarify environment-security relationships. *Environmental Change* considers the manner in which modification of the natural environment – either natural or anthropogenic - influences security by altering the pre-existing availability and distribution of resources, interdependence relationships, geopolitical variables (such as ice-free ports, navigable rivers etc.), the structure of economies, and social or cultural interactions. This may occur as a matter of environmental degradation, sustainability of current practices, physical environmental change, or other mechanism in which changing environmental conditions influence relationships. *Environmental Integrity* takes into account ways in which environmental insults affect security relationships and infers that 'blame' may be affixed – or alleged – and that specific grievances arriving out of the impact of the actions of one security referent on another leads to some level of discord. This may come about via the pollution or other degradation of physical environments or resources; may occur in a clear trans-boundary manifestation or a more subtly ecologically linked fashion; and may even be a case of 'global responsibility' for a situation that otherwise has no clear boundary delineations.

Environmental Resources includes some of the more traditional geopolitical considerations of the natural environment and ways in which resources have been important to the economic and military strength of political referents. Changes of the status quo have been mentioned earlier, but even the existential quality of resource possession is a matter of security consideration. More evident in recent times has been a trend of funding military operations and *other operations detrimental to security* via the control and exploitation of environmental resources. The ways in which natural resources are the object of or have influence on conflict and security are the central considerations. *Environmental Impact on Military*

Operations describes the ways in which the environment impacts the employment and operation of military forces, their platforms, weapons and communications systems, and sensors, etc. This can occur at tactical, operational or strategic levels, but what remains important is the manner in which military scenarios are influenced by variables with a strong environmentally dependent context. *Environmental Impact of Military Operations* considers the fashion in which the employment of military force and the use of various military platforms, weapon systems and sensors, etc. demonstrate impact on the natural environment. This may be viewed over many scales as well, from the physical degradation of the environment during warfare, to impacts that take place during training and peacetime operations, to life cycle considerations which include the utilization of natural resources and pollution by industries that equip and support militaries.

Environmental Influences on International Law is the last subdivision the author suggests because of the ways that environmental issues may influence the development of international law and the subsequent direct and indirect ways that this in turn influences security. Other subdivisions might be argued by other analysts, but what is important is that parsing matters of the environment and security into subdivisions helps initially to clarify relationships. Equally important, however, is consilient interweaving of facets across these subdivisions – an interdisciplinary exercise that makes clear the enormity of sometimes seemingly unrelated issues and demonstrates the relevance of the field of environmental security as a focal area for political science. It is through such a consilient approach that *Beyond the Water's Edge* explores the intersection between matters of the environment and security when ocean science was applied to matters of naval importance.

The first case study of *Beyond the Water's Edge* considers environment-security relationships that were forged when the advent of the modern submarine heralded a shift in naval warfare from two to three dimensions of the ocean battlespace and greatly complicated naval strategies from that point forward. This was initially a tactical and operational issue that involved combat between surface and subsurface platforms and fleets that later reached strategic considerations when ballistic missiles which could threaten civil and military targets were developed and fitted into submarines. Faced with this naval threat at the beginning of the 20th century on through to the present day, the United States Navy became a leader in applying ocean

science to the challenge. After an intensive research and development phase which investigated possibilities from the practical to the impossible, the nascent technology of sonar was arrived at as the optimum solution to address the underwater detection problem. While this was inherently a matter of fluid physics on first principles, oceanography soon became even more integral to naval operations once the nature of sound propagation in the oceans came to be understood as a variable phenomena dependent upon local conditions.

When the exploitation of underwater sound was pushed even further as undersea warfare wore on, it became apparent that ocean structure throughout the water column and even interactions with the seafloor and sea surface were important factors for sound propagation, and that all of these factors varied with the frequency of the sound. This understanding opened the floodgates for investigations of ocean phenomena that extended throughout the water column and at the interfaces between ocean and atmosphere above and between the water column and the seafloor below. Research institutions were founded around the country to bring together talent from other fields which could be applied to important areas of ocean inquiry, and broad areas of basic through applied research were funded to see where investigations might serve up information of relevance to the expansive challenge of undersea warfare. Technologies (such as the bathyscaphe, survey sonars and underwater cameras) which were exploited and further enhanced to serve research requirements revealed additional possibilities through which deep submergence capabilities might address security challenges, including a wide range of underwater espionage activities that have only partially emerged from the shadows of security classification. All the while, through research funded by naval accounts, the rapidly expanding discipline of ocean science identified additional linkages between the environment and security that were important for amphibious warfare, surface and subsurface navigation, resource protection and other areas of naval significance. An important byproduct of this broad research was the development of techniques and technologies to conduct these investigations and their expanded utilization throughout the oceanography community which found applications in both civil and military researches, and which opened the door to additional discoveries in the oceans which fed back to security in ways which were not at all anticipated.

Although ocean research that supported the development of sonar and other underwater technologies in the pursuit of undersea warfare revealed much about the physical, chemical and biological properties of the water column throughout the world's oceans, some of the more critical feedbacks that took place in this timeframe with implications for security related to what was discovered about the seabed beneath the high seas. Issues that arose were of obvious security concern in some respects, but in others the security ramifications were not at all apparent on first examination. Utilizing deep submergence and survey technologies scientists revealed secrets of the deep sea floor which previously had not been an issue internationally because of its inaccessibility, but which now became a matter of contention with man's ability to reach into the ocean depths. The possibility that the United States or Soviet Union might develop the technology to emplace missiles on the ocean floor or otherwise use the area for military purposes – especially more accessible areas along accurately surveyed mid-ocean ridges that might serve to decrease the range requirements of nuclear missiles – concerned many nations and inspired an international accord on the Peaceful Uses of the Seabed. But as significant as that matter was, it was a rather narrow area of agreement soon to be overshadowed by an even larger effort.

Comprehensive surveys utilizing the technologies developed to explore the oceans for naval purposes "rediscovered" seabed minerals – manganese nodules - which subsequently became the object of intense interest for their economic potential. Concern over which nations might exploit these resources *explicitly* catalyzed the process which led to the negotiation of the 1982 United Nations Convention on the Law of the Sea – the most comprehensive body of international law in existence and of direct impact in a number of areas to naval activities and interests. Earlier attempts in the 1950s to construct an overarching body of international law for the maritime realm had also been stirred by advancing undersea technologies which leveraged military research, but these had largely dealt with issues closer to coastlines where countries traditionally asserted some measure of control - although the seaward extent of such control had long remained a matter of contention. When resources became potentially exploitable throughout the oceans and underneath the high seas that theretofore had remained outside the purview of any national authority, the recently enfranchised international community was inspired to act under the framework provided by the United Nations. The establishment of a comprehensive body of international maritime law to address

issues of national sovereignty, resource exploitation, marine pollution and environmental protection, marine scientific research and the navigation rights of seagoing nations held enormous security implications for naval powers. It was a lengthy and multifaceted process that involved a number of complex feedbacks, but the environmental challenges of undersea warfare led ultimately to security concerns in entirely unrelated areas when ocean science was engaged to address the problem…but ultimately engendered altogether new issues.

With the indirect way in which the application of ocean science to a naval challenge created other security implications in the 20th century, the second case study of the present study was selected to investigate if this was a unique second order effect or whether there was a more general principle at work. Ocean science essentially arose in the United States as a matter of addressing naval requirements in the 19th century, not in response to a specific threat such as the submarine, but in a more general way to improve the safety and efficiency of navigation. Navigation was a technical art that mariners perfected to learn where they were when they lacked visual landmarks and to determine a path to where they wanted to go, but it was largely blind to the variables of the natural environment that either facilitated or impeded a ship's voyage between one point and another. Generalities about wind regimes – the trades and the doldrums for instance – were known, as was knowledge of large ocean currents such as the Gulf Stream which aided voyages east but dogged ships headed from Europe to the Americas. But very little was known about the particulars of environmental variables on smaller scales that determined the length of ocean voyages as well as their safe passage outside of these more well-known wind and current regimes.

An aggressive and innovative program to collect geophysical data from naval officers and civilian masters that was begun in the 1840s by Lieutenant Matthew Fontaine Maury of the fledgling U.S. Navy changed the way mariners viewed their ocean pathways ever after. Maury's researches revealed local wind and current regimes and seasonal variations that mariners could systematically leverage to improve their sailing times, avoid particular hazards and spend less time at sea vulnerable to storms. A host of additional data including the frequency and abundance of whales in various ocean areas was included along with more navigationally relevant data and made available by Maury in *Whale Charts* and as comments in his *Sailing*

Directions which were devised to inform the mariner how to best employ the data in his *Wind and Current Chart* series. Once it was established that the application of scientific techniques to the studies of marine weather and ocean currents might improve these aspects of maritime operations, more general scientific investigation of the oceans was supported by the U.S. Navy to determine how much more might be discovered to support these goals. The research cruises that were sponsored supported those intentions by adding to the data Maury collected on marine weather and currents in areas where information proved sparse, but additionally provided enough data from newly developed sounding devices to create the first crude bathymetric map of the Atlantic Ocean and mark the true beginnings of oceanography as a deliberate science. But the story does not end there. While Maury's efforts were initiated to improve the safety and efficiency of navigation – which they did, spectacularly for both naval and civilian fleets – he also had opened Pandora's Box for the many ways security would be affected once the ocean environment had become the subject of dedicated investigation.

The use of the data that Maury made available to mariners was important for naval purposes. It allowed for more regular voyages to far-flung stations around the world for a relatively small navy that needed to maintain a global maritime presence to preserve national interests. It also established techniques that were employed immediately to render assistance to vessels in peril on the seas, methods that continue to the present day through models which help to determine where vessels adrift might be located when rescue forces are dispatched to their aid. But the investigations begun by Maury would have many more implications for security through other ways that they made the oceans less mysterious. The research cruises of the *Taney, Dolphin* and *Arctic* made possible the first bathymetric charts of the Atlantic, and this information illuminated that it would be physically possible to lay a transatlantic communications cable between the Old World and the Americas. Transoceanic communications changed irrevocably security relationships and naval operations, allowing command and control of warships and fleets from thousands of miles away and providing for more responsive utilization of both naval forces as well as ground forces that were transported to areas of conflict by naval means. The laying of submarine cables additionally stirred the waters of international maritime law over rights to lay the cables and over the cutting of cables between

adversaries and neutral nations in time of war - a harbinger of things to come when seabed issues again would be considered alongside more traditional law of the sea concerns.

The application of ocean science to maritime operations pioneered by Maury also had the unique side effect of providing a means for a lesser naval power to select a *guerre de course* strategy that it utilized to great effect by exploiting the geophysical guidance intended to improve navigation for targeting the commerce of its opponent in the U.S. Civil War. Not only was the North's carrying trade pursued in this fashion by the Confederacy (and virtually extinguished when merchant ships were sold to foreign interests, essentially destroying the American carrying trade even after the war), but so was the whaling trade when Confederate raiders sought the Yankee fleet in the whaling grounds suggested by the information in *Maury's Sailing Directions* and that were depicted on his *Whale Charts*. Years before this martial use of geophysical data, a more peaceful collaboration between maritime states to gather oceanographic and atmospheric observations at sea was established as an outcome of perhaps the first international environmental conference – an agreement that was considered to transcend the bounds of conflict in the collection of data and the protection of logbooks in the event of capture in time of war. Years later this would prove of importance in establishing the rights and privileges of vessels involved in ocean research as matters of maritime law. The original aims of oceanographic inquiry – to improve the safety and efficiency of navigation at sea – were met with great effect as a result of the first long term and systematic investigations of the oceans, but in the process a host of security implications arose again as a result of complex feedbacks that stemmed from the initial application of ocean science to environmental challenges to naval operations.

The impact of environmental constraints on naval operations is again demonstrated in the contemporary (and complementary) 21st century case studies of *Beyond the Water's Edge*. In the first, the central security issue is an extension of the submarine challenge that precipitated much of the application of ocean science to naval problems throughout the better part of the 20th century in both World Wars and throughout the Cold War, but that is further complicated by the additional geophysical challenges of undersea warfare in the littorals against even quieter modern diesel submarines. To address these challenges, the United States

Navy renewed efforts begun late in the Cold War to develop active low frequency sonars which had originally been proposed to pursue Soviet nuclear submarines designed with more effective quieting technologies to defeat passive detection via the undersea surveillance systems which had been employed with significant success during that conflict. Civilian scientists collaborating with this research recognized that the same technology might be employed for other purposes, and pursued the development of acoustic tomography – a technique to examine ocean phenomena including the basic understanding of mesoscale ocean processes of circulation and thermohaline variance, but also formidable questions related to long-term climate change which had been identified as perhaps one of the most important environmental issues of the post-Cold War world. When these parallel efforts became entangled with environmental concerns over their potential to harm protected species of marine mammals and other marine life, a new vein of international environmental law was opened into the consideration of underwater sound as a transboundary environmental pollutant. Opposition to the use of low frequency underwater sound began in U.S. courts when environmental activists and conservation groups became aware of the development of these technologies and their *potential* impact on both the physical well-being and biologically significant behaviors of marine mammals. Later, when mid-frequency range naval sonars demonstrated impacts on species of beaked whales that became the subject of high-profile stories in television and print news media, opposition spread internationally and began to move the levers of international action against the use of high intensity sonar in general and not merely the low frequency systems that had initiated environmental concerns. A still-developing aspect of international maritime law, this variable has important ramifications for naval operations with respect to the predominant technology developed to pursue antisubmarine warfare, but also for the employment of naval forces in general within a framework of potentially more restrictive rules governing coastal waters and other biologically significant areas as a matter of environmental protections.

In the final case study of *Beyond the Water's Edge* another technology with relevance to naval interests as well as environmental ones was investigated, an ocean remote sensing device which became the victim of bureaucratic and budgetary decisions that may remove it from the inventory altogether: satellite altimetry. Spaceborne altimetric sensors were first developed and flown in the 1970s and 1980s to resolve

geophysical environmental parameters important for submarine warfare. Once initial mission aims had been achieved, the sensor which was flown on the GEOSAT satellite was moved into an exact repeat orbit that demonstrated its utility for examining mesoscale ocean variables which were important environmental parameters for describing the ocean environment as a matter of submarine warfare, but that also provided critical data for climate change studies including sea level rise and mesoscale processes of ocean circulation. Subsequent sensors were flown on both military and civil satellites, but through a series of programmatic and budgetary decisions are imperiled as sensors for future remote sensing missions - in no small part because of the end of the Cold War and a concurrent decrease in emphasis on antisubmarine warfare that has only recently been reconsidered as a matter of naval importance with the proliferation of diesel submarine technologies to potential adversaries of the United States Navy.

Satellite altimeters will remain on orbit at least through the next several months, but after that will exceed design life and can not be depended upon to provide data that initializes naval ocean models that affect many aspects of naval warfare, but that are particularly relevant to providing the environmental information necessary to drive acoustic propagation models which inform tactical decision aids – the loss of which will affect the ability of naval forces to pursue effective strategies of antisubmarine warfare. The possible loss of altimetry for studying mesoscale ocean variables – which incidentally might also be studied through methods of acoustic tomography with certain tradeoffs related to spatial coverage – becomes of further concern with the growing awareness that *abrupt* climate change may possess greater potential to affect security interests than previously anticipated with respect to long-term climate change concerns. Greater understanding for atmospheric and oceanic teleconnections associated with abrupt climate change highlights more and more environmental variables with security ramifications in far-flung areas related to environmental security through impacts on resource availability and the carrying capacity of large regions of the world already burdened by environmental problems which complicate political, ethnic, religious and other forms of conflict. Nascent areas of military interest related to humanitarian assistance and disaster response to incidents such as tropical cyclones is also dependent on information provided by these technologies and will be impacted by the potential loss of their availability in the future. In a complicated

post-Cold War world security environment, complex naval challenges interweave environmental and security concerns in ever more convoluted ways.

Each of the case studies of this work began with an environmental challenge to naval operations, which blossomed into other areas of security relevance once the strategies identified by ocean science engendered feedbacks which affected security considerations that were sometimes relevant to the original challenge but that often wended into areas significantly different and perhaps even more consequential. Each of the initial challenges existed at the tactical and operational levels of warfare: they impacted the employment of naval assets and the strategies that were engaged regionally to answer naval challenges such as antisubmarine warfare. The feedbacks that resulted however, sometimes transcended these levels to the strategic level – the ability to employ naval forces to achieve national goals which were affected by such considerations as the impact of international law under UNCLOS or that involved challenges of a scale such as that represented by climate change in either its long-term or abrupt manifestations. It is of some interest that challenges and feedbacks related to the environment didn't initiate in any of these cases from the opposite perspective; climate change as a strategic security concern did not take root to influence environmental studies which translated to the tactical level, and as a subject of interest itself was entirely dependent upon the technologies developed to address tactical and operational levels of naval warfare both as a matter of undersea technologies and satellite observational methodologies. The identification of environmental parameters of interest to naval operations was the driving factor in both focused and broad areas of ocean investigations which led to discoveries and to feedbacks at the larger level of analysis.

Contemporary opposition on the part of some environmental activists to the co-option of environmental problems as security ones fails to recognize that much of the understanding of environmental problems and challenges arose from the opposite perspective of addressing environmental constraints on naval and military problems. While it is nether likely nor appropriate that all environmental concerns be recognized as security ones, it is of consequence that the national will to investigate the environment – for while many parameters have become the subject of investigation by intergovernmental and non-governmental organizations, they often began as the endeavors of individual nations and in the

oceans many of these uniquely by the United States – resulted from the perceived security interest that such investigations supported. Large scale environmental science serves many purposes, but is also extremely expensive; security imperatives which motivated research from what might be considered "beneficial" to "essential" were the critical catalysts. Something of a truism in other areas such as advancements in certain forms of technology that grew from military research and development (the computer, shipbuilding and aviation and space technologies were all leveraged in this fashion), this is an especially important factor in environmental studies which require research on a scale that can be supported by national treasuries more so than lesser levels of investment. When security is at stake, public coffers are more easily levered open. This approach is more tractable when challenges manifest at tactical to operational levels with more concrete obstacles that need to be overcome – in evidence with even the substantial investments made in the study of ocean variables to address naval challenges. Resolve wanes, however, when the problem is more abstract; while climate change is considered a matter of security primarily at the strategic level (if even viewed through a security lens at all), it will remain more difficult to address and receive less emphasis as a matter of security interest…and as a matter of research investment when compared to other environmental parameters that can be directly linked to military requirements at tactical and operational levels of warfare.

Investment in ocean science examined in each of the cases of *Beyond the Water's Edge* follows this general rule that specific topics of the field were pursued primarily to satisfy requirements in support of the national interest first, with lesser emphasis yet evident awareness that what was discovered and could eventually be declassified would inform the broader goals of the science as well. Maury's work clearly was supported – and largely undertaken in its early years – exclusively through naval means (which by definition existed in support of the national interest), but even expansion into commercial shipping through the recruitment of masters to record his data should be viewed in this light. The lines between professional mariners in naval and civil pursuits were much more grey for one thing, with Navy sailors and officers often being placed on half-pay leave for years on end and serving as civilian mariners in the interim; but also the pursuit of maritime commerce was much more a hand-in-glove activity with naval support in the 17th and 18th centuries of mercantile fleets. The showing of the Flag by naval ships on round-the-world

cruises was a none-too-subtle message: meddle with our commercial fleets at your own peril. Rising tides of technology and knowledge in the oceans truly lifted all mariners and all boats at this time; Maury's researches to improve the safety and efficiency of navigation were universally applied for all who sailed the sea.

Underwater signaling with sound was originally researched as a matter of protecting ships from navigational hazards, and moved closer towards modern sonars once the *Titanic* disaster registered on the public consciousness, but it was not until the u-boat menace of WWI that a Manhattan Project-like effort was undertaken to assess the possibilities for underwater detection and that selected and pursued sonar as the primary means. Because the technique was dependent on environmental variables on basic principle and in operational use, it opened the window into the importance of ocean research and monitoring from that time to the present day. The many techniques and technologies that were devised to pursue these goals and other naval challenges fostered the subsequent feedbacks that complicate environmental security in the oceans in various non-linear ways. Underwater technologies are particularly expensive to develop and to implement because of the harsh operating environment in which they function. Without the security imperative to pursue their development and refinement, they would not likely exist in other than rudimentary forms and many of the greatest discoveries within the ocean depths would remain beyond observation in the opaque waters. The sonars that map the ocean depths; the sounding and sampling devices which sample the ocean floor and water column; the cameras that capture images that human eyes will never see unaided; the manned submersibles and tethered and free-swimming robots that explore the depths; the magnetometers that revealed the processes of seafloor spreading and the gravimeters which helped scientists to understand important geophysical relationships of the earth's structure; the satellites which record images and measure ocean and atmospheric variables over scales otherwise unachievable; the oceanographic universities which train scientists and provide facilities for the conduct of research into the oceans: virtually all can be traced in some percentage to the naval requirements which inspired research and started the money spigot. Scientists who would claim otherwise – especially in the field of oceanography – would have a difficult time if they traced their own training, current research, or the research that underpinned what they themselves conduct to demonstrate no earlier connections to naval

requirements. That may be too simple a statement if the lineage is traceable almost everywhere to Maury, but even with the present day popular notion of "six degrees" of freedom connecting various parameters, in the field of oceanography it is likely more realistically two, and perhaps at the furthest imaginable maybe three before a substantive connection to security could be discerned.

From all indications the United States Navy will continue to employ ocean science in the pursuit of naval requirements, but the relationships investigated in this study suggest that a more consilient approach will facilitate both the goals of the research and for dealing with the second order effects that such research might engender. Two examples from the present day serve as possible ways in which this type of approach to research and operations might be pursued. Satellite altimetry and low-frequency acoustics both have applications for antisubmarine warfare which has been identified once more as a priority for the U.S. Navy. And both technologies have important applications for climate change research which has potential to be of importance for security ramifications, but which irregardless has been identified as an issue of importance for the international community. A renewed commitment to altimetry will serve antisubmarine warfare efforts and other naval requirements to characterize the operating environment through the observation of ocean features and to provide initialization data for ocean modeling efforts, but pursuit of advanced altimetric technologies would additionally provide data for climate change research which will enable the U.S. to contribute to the monitoring and prediction of climate – a critical role for the United States as the subject of criticism for its own carbon use and for its failure to join the Kyoto Protocol for reducing the amount of carbon dioxide it emits. While difficult to quickly design and fly new satellites, sensors such as the wide scale ocean altimeter might be reintegrated onto the JASON-2 mission and provide the coverage of multiple pulse-limited altimeters currently on orbit. A free-flying delay Doppler altimeter such as ABYSS-Lite would also serve some mesoscale observing requirements and additionally serve to map the ocean floor at twice the resolution as has been accomplished to date. Both of these technologies would be justifiable for their contributions to naval requirements and both would facilitate climate change research. While neither would be a cheap solution, both would demonstrate the commitment of the U.S. to research that is important to other nations while still supporting its national interests through the naval applications of the data each satellite sensor would provide.

Low-frequency acoustics also bears a second look. The U.S. Navy has committed to this technology for long range detection capabilities that LFAS offers over other antisubmarine warfare technologies. Despite intense scrutiny there have been no documented cases where low frequency sonars have harmed marine mammals, as the ICES report detailed for the European Parliament which was specifically concerned over the use of this technology. Ongoing operational use of the sonars in the Western Pacific provides additional data on the effects of low frequency sound on marine life on a quarterly basis at classified levels that are summarized annually in unclassified reports. The only case related to sonar usage in which marine mammals were harmed that *might* have involved low frequency – the Kyparissiakos strandings – also involved mid-frequency range sonars, and it appears from the implication of these sonars in other cases in the Bahamas and Canary Islands that ensonification of beaked whales in this frequency range was more likely the culprit. Much of the research that was focused on the use of low frequency sonar is applicable for evaluating the effects of MFA sonar as a matter of developing environmental impact statements for its use for training and operations off the Atlantic coast and around Hawaii. Renewed emphasis on low frequency sonar may be in order now that mid-frequency range sonar appears more likely to impact marine mammals and equally likely to be restricted for this reason; at the same time a second look at its corollary technology acoustic tomography for climate change studies would again provide important data for this area of environmental concern.

A unique approach to the use of low-frequency sound underwater might be in order that is informed by other areas of environmental law – the use of "credits." Despite the focus of environmental groups on low frequency sonar and acoustic tomography as underwater pollutants, it is acknowledged that combined these technologies supply only a minute fraction of low frequency underwater sound in the oceans. Commercial shipping and acoustic surveys using airguns dwarf the contribution from LFAS and ATOC/NPAL transmissions. If the United States were to take an active role in negotiations over underwater sound as an underwater pollutant, it might seek to establish a program similar to one used for atmospheric pollutants such as sulfur dioxide or carbon dioxide that would provide offsetting credits for the use of underwater low frequency sound. It would be fairly straightforward to establish a sound budget at these frequencies as a

result of shipping and other technologies which introduce low frequency sound underwater, and to then document the offsets that could be accomplished to balance or exceed the amount of sound that would be introduced either by LFAS or ATOC/NPAL transmissions. The United States might develop and transfer quieting technologies for ships or subsidize the upgrades that would be required to help to quiet shipping in these frequencies. The U.S. could then employ its sonar technologies – with all of the other monitoring and mitigation strategies already developed related to their responsible use – and still address the growing recognition of sound as an underwater pollutant in a proactive fashion. This would be an unprecedented move to offset a military technology with improvements in areas of civilian use that currently go unregulated in the world oceans - the type of consilient approach that might not be apparent at first blush but that becomes evident with a more ecological view of the phenomena involved.

Final Connections

It is not surprising that oceanography as a science would be central to a study exploring consilience across disciplines to further develop themes of environmental security. Its growth as a field and even the use of oceanography as a term represented the coming together of diverse disciplines of marine biology, marine geology and geophysics, marine chemistry and fluid physics because of the inherent need to work across these disciplines to study marine phenomena. This has also brought a number of figures to the field who were also comfortable across a large range of interests and specialties and who color this study through the range of their talents and the individual diversity they possessed. Their strengths in one field were important to developments in others, and they all had naval ties. Maury was a naval officer with an interest in ocean science. He was able to bring the resources of the Navy to study the problem, and the success and recognition he received in the process made possible the 1853 Brussels Conference – the first international environmental conference and the progenitor of the World Meteorological Organization – as well as the successful laying of the Atlantic Telegraph, both as a result of the marine surveys he dispatched as well as his reputation as the expert most capable of assessing the possibility that a cable might be laid across the broad ocean.

Walter Munk's early achievements in oceanography included solving important operational problems which were obstacles to amphibious landings in World War II; his work in ocean acoustics was important throughout the Cold War and his championing of acoustic tomography was integral to the part that technology has played and has yet to play in this story. One cannot be sure of projecting the present day into the future for such a technique as acoustic tomography that will likely face continued opposition from environmental groups, but the author ventures that it is far from moribund. Roger Revelle began his career in the oceans as a naval officer and went on to make an important mark on national science through his work after the war both in government positions that sponsored scientific research in the oceans and elsewhere, and also through his leadership at the helm of Scripps Institution of Oceanography. Revelle's interest in the carbon question that grew from the studies at Bikini Atoll led to his hiring of Dr. Dave Keeling to study the problem; Keeling's famous Curve is perhaps the symbol for climate change research. Jacques Cousteau became famous as the great explorer of the oceans for generations of post-World War II television viewers, and a great advocate for their protection and conservation. Few realize Cousteau began as a French naval officer whose early oceanographic interests can be traced to work with Auguste Piccard's *FRNS-2* bathyscaphe and whose work on diver rebreathing technology which led to the aqua-lung was supported by the French Navy and government. The polymath Piccard – who first gained notoriety through his researches in the upper atmosphere – gained fame in the oceans for his bathyscaphes, and the development and many accomplishments of those and subsequent craft owed a great deal to the support of the French, Italian, and United States Navies. Perhaps the most famous ocean explorer of the present day is Robert Ballard, the discoverer of the watery grave of the *Titanic* and other famous shipwrecks. He too began his career as a naval oceanographer in uniform, and virtually all of his technological innovations and researches were funded by the United States Navy.

For her importance to the growth of the environmental movement, and the importance that environmental protection and conservation have to the study at hand, special consideration should be given to Rachel Carson in this narrative. Carson's *Silent Spring* has been considered the clarion call for protecting the natural environment from the ignorant and indiscriminate polluting hand of mankind, and traced in numerous ways to other awareness drives and movements and to the growth of environmental

legislation to enforce protections in the United States and abroad. But Carson's fame actually antedated *Silent Spring* and in fact was the reason she was put in the position to research and write that work which has since become synonymous with her name and overshadowed her earlier undertakings. Carson began her career as a marine biologist and while accomplished in her field in her own right worked in relative obscurity as far as the world outside of academia was concerned. World War II changed all of that, for Carson was interested in doing her part, and through her contacts at the Woods Hole Oceanographic Institution managed to get a job vetting ocean research projects in support of the war effort. After the war, Carson realized how much had been learned by the research that had been conducted to support naval requirements across a broad range of ocean disciplines, and decided that the public should be made aware of how the opacity of the seas had been parted by the light of knowledge.

Rachael Carson's gift was her ability to translate the importance of research into beautiful prose that not only informed but entertained. *The Sea Around Us* became a best seller and was later made into a movie. The underwater world that had been so intently studied as a matter of security interests subsequently captured the public imagination. Carson's success with *The Sea Around Us* led to the republishing of an earlier work that had languished quietly outside the limelight, *Under the Sea-Wind* and a follow-on work, *Edge of the Shore*. These three works hit the trifecta; even as works of non-fiction they represented the first time that a single author had three books on the *New York Times* Bestseller List. Both as a successful author and as something of a rarity in the 1950s as a female scientist, Carson became a celebrity. It was this celebrity that led interest groups to seek Carson's help in addressing the potential dangers of pesticides and other chemicals that man was using to alter his physical environment intentionally and as a byproduct of other activities. Carson initially demurred and offered to write to some officials she knew that might help the activists in their work, but when she was rebuffed it angered and inspired her to her seminal work on the subject.[1] The environmental movement in its entirety – the collective programs of education and awareness, activism, legislative lobbying, and the fieldwork that conducts conservation projects and research – which traces its lineage to this brilliant author and scientist unknowingly tips its hat to the research in the oceans that was undertaken as a matter of military necessity.

[1] Carol B. Gartner, *Rachel Carson* (New York: Frederick Ungar Publishing Company, 1983).

In some way worthy of mention, although not strictly a matter of environmental security in the oceans nor of consilience as a matter of cross disciplinary analysis, is the role played throughout this dissertation by the whale. Cetaceans have been described as charismatic megafauna for the manner in which they inspire mankind to rally to their defense when threatened and for the numerous ways that these creatures inspire some unexplainable kinship with man. Whales have come to be viewed as sentient creatures and not merely just large animals that provided meat and oil and other products to earlier generations. This is not a uniquely modern phenomenon; historically whales have been afforded allegorical meaning as far back as Jonah, and Melville's *Moby Dick* certainly treated the whale as anything but a dumb brute. It was not expected that the whale would wend its way so thoroughly throughout *Beyond the Water's Edge*, however…yet it did. As recounted in the second case study, Maury's *Whale Charts* informed 19th century whalers where to hunt for the mammals, but in an ironic twist also served to show Confederate raiders where to hunt for the whalers. The *Whale Charts* represent almost the only data prior to the 20th century and to this day are the benchmark to demonstrate change in numbers and distributions for a number of whale populations around the globe. Maury's anecdotal discovery reported in *The Physical Geography of the Sea* that a whale captured in the Pacific still had a harpoon lodged in it by an Atlantic whaler led to theories of northern passages or at least open areas where whales could surface to breath on a trans-Arctic voyage.

While the satellite remote sensing issue considered in the first contemporary case study does not directly link to cetaceans, the complementary 21st century case study of ocean science and security interactions involving acoustic methods is so obviously a story which involves the whale as to not merit too much analysis; but it is significant that the whale is such an important charismatic megafauna that the mere association of it with potential harm from ATOC, then LFA and then MFA sonars inspired the intense legal action that it did - and possibly even may lead to developments in maritime law which treat sound as a transboundary underwater pollutant. It is also of note that one of the first swords-to-plowshares initiatives after the end of the Cold war was to track whales with the formerly top-secret SOSUS system by recording their vocalizations at low frequencies; the association of this critical technology so central to the entire

Cold War story of ocean science and security with cetaceans furthers the perhaps coincidental but in some way repetitive linkage between the whale and this study. The 20^{th} century case study has perhaps the fewest ties between the whale and matters of ocean science and security, but they can still be made for this time period. The growth of Greenpeace as a movement over its "Save the Whales!" campaign led to its later involvement with opposing ocean based nuclear testing – an interesting story of intrigue and derring-do by both Greenpeace and the French Navy that remained largely outside the bounds of this current study. Whales were also a matter of some significance during WWII and afterwards for their similarity in appearance to a submarine operating at periscope depth; more than one whale inspired a "scramble" to intercept an adversary submarine, and unfortunately more than one whale met an untimely end when bombed or depth-charged as a result. An interesting identification pamphlet from the early 1960s has pages of photos to help aerial observers distinguish a surfacing whale from a shallow running submarine.[2] But there is one way that whales can be very closely tied to the central theme of the first (20^{th} century) case study: the United Nations Convention on the Law of the Sea was inspired - through a few feedbacks - by military research in the oceans, and the *cause celebré* that catalyzed the Law of the Sea negotiations was manganese nodules. These marble to potato sized accretions of manganese and other important metals form concentric layers over centuries around a hard inner core which often is found to be shark teeth or the *ear bones of whales*!

The case studies of *Beyond the Water's Edge* were investigated to determine how the securitization of environmental parameters that were related to naval challenges affected the security of the United States, but in the process also sought to examine what this meant to the field of environmental security in general. As a maritime nation, the U.S. will continue to depend on its naval forces to protect its national interests in the maritime realm, and operating upon, over and under the surface of this geophysically variable region will mean that the United States Navy will remain interested in environmental variables that affect operations. The recently stated vision of the Commander, Naval Meteorology and Oceanography Command emphasizes the Navy's commitments, "*Naval Oceanography* ensures successful execution of the Navy Strategic Plan. It underpins every aspect of Naval operations and warfare. It provides an affordable

[2] United States Navy, *Submarine Recognition Manual* (Washington, D.C.: United States Government Printing Office, c. 1960), NAVPERS 10011.

and sustainable competitive advantage to our Navy and nation. It protects our substantial National investment in both afloat force structure and shore sites. *Naval Oceanography* is the comprehensive technical authority on all aspects of the natural environment in which our Navy operates and fights [original emphases]."[3] Investigations into new challenges and ongoing monitoring of environmental variables known to affect naval operations will maintain the U.S. Navy at the forefront of ocean science and security. It is a rich area for future research that will likely see new environment-security intersections arise because of increased pressures to investigate the marine environment for natural resources – utilizing of course the technologies developed to pursue naval research – and further test the boundaries of international maritime law. It is the author's sincere hope that the cases presented here demonstrate the importance of the ocean environment to security considerations; that they help to resolve and clarify some of what takes place when the environment is investigated to serve naval requirements; that they demonstrate that environmental security has relevance that extends far beyond simply the potential for environmental issues to incite conflict; and that they demonstrate that consilient approaches not only help to understand what has occurred when matters of the environment and security intersect but provide insight into how events might unfold in the future.

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[3] Timothy McGee, *Battlespace on Demand: Commander's Intent* (Stennis Space Center: United States Navy Meteorology and Oceanography Command, 2006).

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